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ABSTRACT

Choosing a career can be a time consuming and difficult task. This book is intended to serve as a reference for today's youths as they make decisions on their career goals and college education. The book contains descriptions of the various scientific and engineering fields and their associated requirements, guidance in college curriculum, and biographical examples of successful scientists and engineers. Also included is a listing of the national, regional, and local education programs for teachers and students sponsored by the Department of Energy, National Aeronautics and Space Administration, and the National Technical Association. (ZWH)

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Careers in Science and Technology

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Careers in Science and Technology

Department of Energy

National Technical Association

National Aeronautics and
Space Administration

September 1993

Astronaut Charles F. Bolden, mission commander, talks to amateur radio operators on Earth from the flight deck of Atlantis *during the STS-45 mission of the Atmospheric Laboratory for Applications and Science (ATLAS). The Space-to-Earth communications were part of the continuing Shuttle Amateur Radio Experiment (SAREX) project.*

Foreword

The United States Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA) are both committed to achieving the National Education Goal for U.S. students to be first in the world in science and mathematics achievement. In recent years, numerous publications and reports indicate that our nation is falling behind others in science and technology and will be at an increasing disadvantage in the international economic competition in high-technology goods and services. This is especially true as we review the statistics related to the training of new scientists and engineers, particularly minorities and women.

The National Technical Association (NTA), a nonprofit organization of professional scientists and engineers founded in 1926, DOE and NASA have produced *Careers in Science and Technology*. The purpose of this book is to serve as a reference for today's youth as they make decisions on their career goals and college educations. Some students seem to lack the confidence that they can actually become a scientist or engineer. This book's contents include descriptions of the various scientific and engineering fields and associated requirements, biographical examples of successful scientists and engineers, and guidance in college curriculum and career selection and in proper study regimen… all helping to define a clear path for obtaining a career in science, engineering, or technology. The book was written by practicing scientists and engineers who give their own first-hand experiences and are dedicated to helping and inspiring students to pursue the excitement and challenge of scientific careers.

DOE, NASA, and NTA offer many national, regional, and local education programs for teachers and students. This book lists the contacts for pursuing these education opportunities.

Health scientists conduct research to improve and discover new medical treatments.

Preface

The objective of this book is to expose junior and senior high school students to the science and technology fields. It also will convey the importance of getting a general education in science and mathematics while still in high school and of continuing such studies in college. This is intended to encourage students, particularly underrepresented minorities and women, to consider and prepare for careers in science and technology. This book attempts to point out the increasing importance of such knowledge in daily life regardless of occupational choice.

This book is intended to be used by junior and senior high school students, as a classroom reference by teachers, and by scientists and engineers participating in outreach activities.

The present is a time of very rapid change, both in the occupational arena and in daily life. Perhaps the technology area with the most widespread impact is computers. Predictions of today, made 25 to 50 years ago, demonstrate that this is the major area of development that was not foreseen.

As recently as the advent of the space age in 1957, the United States was the undisputed world leader in science and technology. Competition with the Soviet Union was a major driver of science and technology in the United States from the late 1950s through the 1980s. Today, the Soviet Union no longer exists, and we face increasing competition from Japan and other nations in the Pacific Rim and Western Europe.

At the same time, a smaller percentage of students in the United States are choosing careers in science and technology, and the quality of science and mathematics education in public schools has declined. An additional concern is that minorities and women are not well represented in the scientific and engineering professions. This disparity is obvious at the college undergraduate level and even more so at the doctorate level. A major factor is that these groups have less exposure and encouragement in elementary and high schools.

One of the main objectives of the National Technical Association (NTA) is to encourage students to consider careers in science and technology. Career awareness programs (CAPs) are important aspects of the activities of NTA and its local chapters. This book, describing science and technology career opportunities and educational requirements, will aid and complement the CAP activities.

There are many career brochures published by the various specialist scientific and technical societies. However, no general career book exists that describes a wide range of science and technology fields, with accompanying career options and academic requirements. Since NTA covers a wide range of scientific and technical specialties, and is particularly committed to exposing students to these areas, NTA was the appropriate organization to carry out this task.

In writing this book, source materials (listed in the Appendix) published by the National Aeronautics and Space Administration (NASA), the American Association for the Advancement of Science (AAAS), the National Science Foundation (NSF), and other organizations were used. Contributions of photographs and other materials were made by the NASA Headquarters Education Division, Office of Equal Opportunity Programs, and Office of Public Affairs; Goddard Space Flight Center, Lewis Research Center, Langley Research Center, Marshall Space Flight Center, the Ames Research Center, and the Naval Research Laboratory; also by Howard University, Black Collegiate Services, Inc. (publishers of the *Journal of the National Technical Association* and *The Black Collegian*), Jackson and Tull Chartered Engineers, and several others.

Listed in the Appendix are other publications containing biographies and other materials supplementary to those presented here, as well as videotapes useful and relevant to teachers and in community outreach activities.

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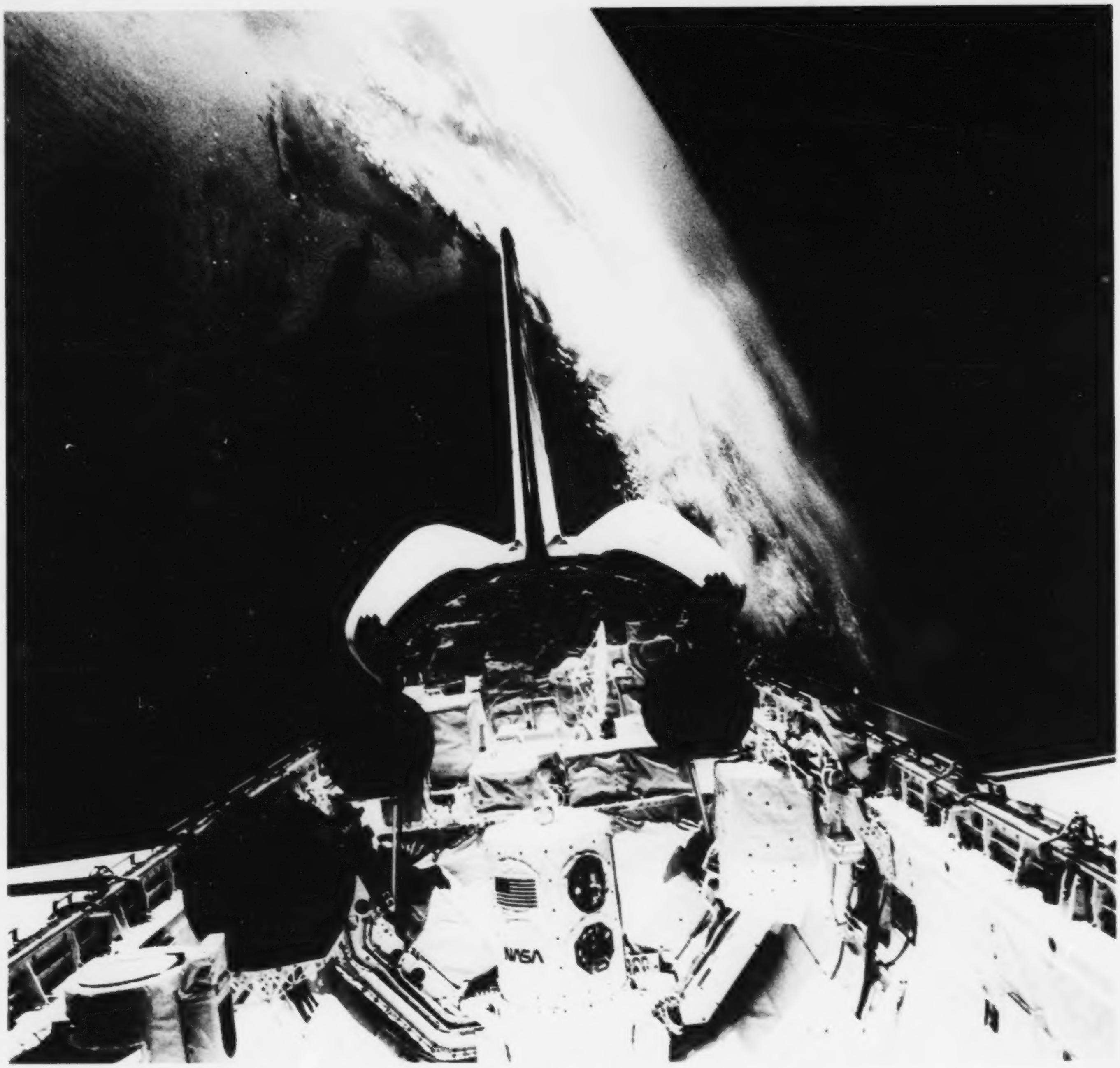
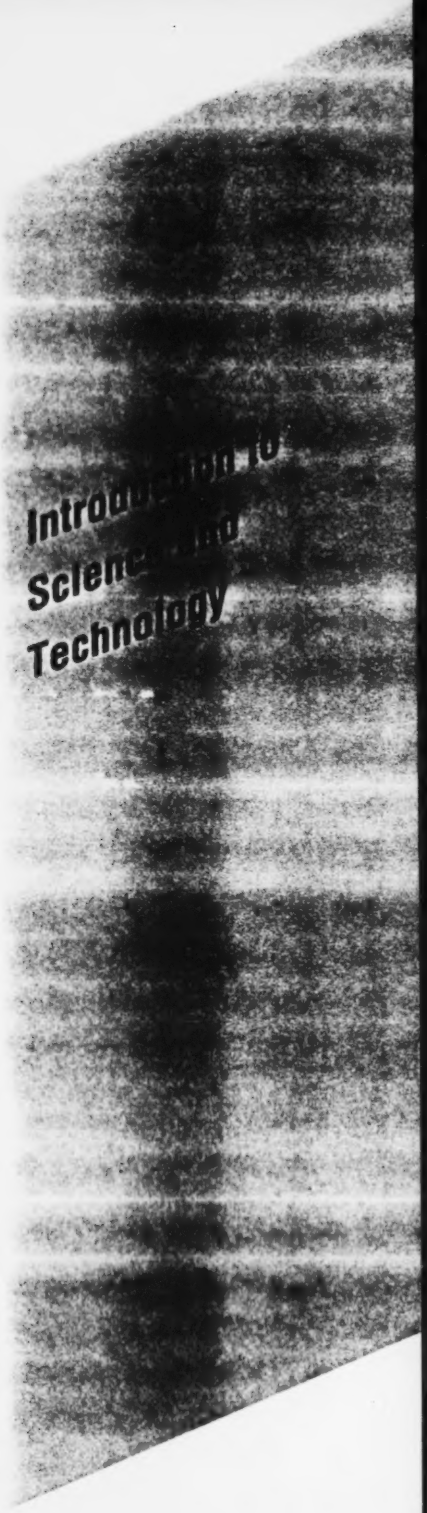


Atmospheric Laboratory for Applications and Science (ATLAS) pallets are backdropped against the Atlas Mountains. This view was taken during STS-45 from a point over Mali in western Sahara



Introduction to Science and Technology

Space Shuttle reaches high into the night sky at Launch Pad 39. This unusual photograph was taken with a fisheye lens.

Chapter I. Introduction to Science and Technology

The objective of this book is to expose you to the fields of science and technology, both as areas in which you should have some knowledge (regardless of your occupational goals), and to encourage you to consider these areas as career opportunities.

The fields of science and technology are not sharply defined; they encompass a very wide, overlapping range of fields including mathematics, science, engineering, and other technical disciplines. Mathematics is both a tool used in the remaining areas and a field of research in its own right (like science). Science is defined as the search for new knowledge; for example, basic research into the laws of nature. Engineering is applying existing scientific knowledge to solve practical problems such as designing a new aircraft or a nuclear reactor. Technology is defined as the process of producing goods and services; for example, using a computer to analyze the company budget.

A nuclear physics laboratory provides a demonstration of how scientists, engineers, and technicians would be involved in a project. The scientists decide that to study the structure of an atomic nucleus, they need an accelerator that produces a high-energy beam of protons (elementary particles that are part of the nucleus of an atom) which they will use to bombard samples of various materials. Based on their knowledge of physics, they determine what energy the protons must have, and how many particles per second are needed (beam intensity). They may also develop a concept of what the accelerator would look like. Engineers further develop these concepts, based on their knowledge of basic physics and its applications to electrical and mechanical engineering, and create a detailed design of the accelerator. This design is given to technicians who construct and test the accelerator. After the accelerator is in full operation, other technicians operate it for the scientists.

Of course, there is a good deal of overlap among science, engineering, and technology. For example, scientists often design new instruments to use in their research. Engineers sometimes do research into the properties of materials to find better ones to be used in hardware that they design. It is also difficult to draw a sharp line between the jobs of an engineer and a technician. The newly emerging area of computer science is actually a combination of mathematics, electrical engineering, and other specialties. In this book the terms science and technology or technical field are used to mean any or all of the fields or occupational areas described above.

The benefits of science and technology to humanity are many and obvious. We fly from coast to coast in five hours; it used to take a week by train. Many improvements in medical care have resulted from basic research and technological advances in biomedical and biochemical fields. Computerized word processing has greatly increased the efficiency of preparing typewritten documents. And what would it be like today without copying machines? Automatic tellers allow us to withdraw money 24 hours a day, seven days a week — not just during "bankers' hours." Microwave ovens cook our food in a fraction of the time of conventional ovens. Video-cassette recorders allow us to tape television programs, and to see first-run movies at home. Compact video cameras have made home film movie cameras and projectors old-fashioned. Telefax machines, electronic mail, and cellular telephones have greatly expedited communications.

In basic science, there has been a virtual explosion of new knowledge in the last few decades, and in some fields, surpassing the total of all the previously gained knowledge since the dawn of humanity. For example, spacecraft sent to the outer planets have returned detailed images and other measurements of the planets and their satellites, which are not only invisible from Earth to the unaided eye, but were not even discovered with large ground-based telescopes until the 19th or early 20th century.

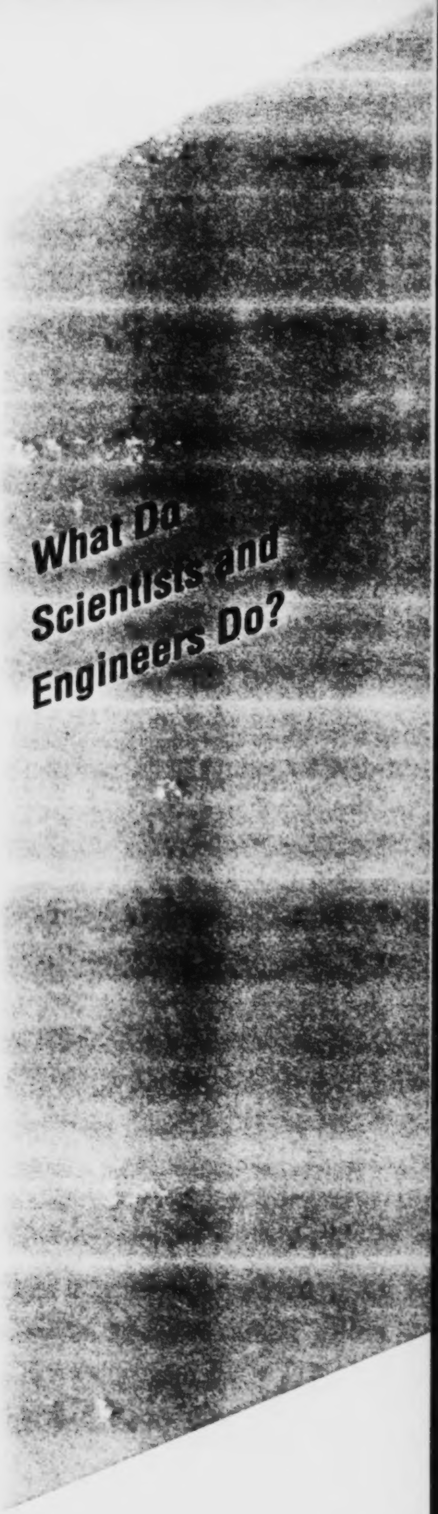
People who pursue careers in science and technology derive much excitement and satisfaction from contributing to the practical benefits of science and technology, and also to the acquisition of new knowledge that is the foundation of future technological innovation. Everyone who is interested in careers in these fields should have the opportunity and the encouragement to pursue that interest.

Most areas of science and technology require a basic, broad knowledge of science and mathematics. As mentioned, mathematics is a fundamental tool of nearly all scientific and technical fields. A knowledge of mathematics and the three basic sciences — biology, chemistry, and physics — is essential regardless of the field of specialization you choose.

Unlike many other career areas, science and technology require a proper education beginning in high school (or even in elementary school). If you wait until you enter college to decide to study science or engineering and have not taken the prerequisite science and mathematics courses in high school, it will be more difficult and take longer to complete your degree requirements. Therefore, it is important to be aware of the basic requirements in science and mathematics and to take the necessary course work at your earliest opportunity.

Because of our increasing dependence on technology, even people who do not choose careers in technical fields must have some knowledge of these basic four. For example, computers are now used in the business, legal, and financial fields, not just in technical ones. Secretaries use word processors, and musicians use computer-based synthesizers. A taxicab driver should have a knowledge of the basic principles by which his or her vehicle operates to optimize his/her fuel economy and minimize repair bills. Even the homeowner has an increasing need for some technical knowledge to maintain the home and operate the newer household appliances.

Looking to the future, it is clear that we will become more and more dependent on technology and that we will need to maintain the basic scientific research that is its foundation. To meet this demand, we must have well-trained scientists and engineers. The following chapters of this book describe in more detail what scientists and engineers do, the educational requirements for technical careers, and post-college occupational opportunities.



What Do Scientists and Engineers Do?

Astronaut Edward H. White II floats into space, secured to the Gemini 4 spacecraft by a 25-ft. tether line. White became the first American astronaut to exit from his spacecraft while in orbit.

Chapter II. What Do Scientists and Engineers Do?

Perhaps the best way to understand the technical fields of study and the technical occupations is to have a brief overview of these fields and the types of work available in them. In particular, it is helpful to have detailed examples of the work done by people in specific fields. Accurate descriptions and persuasive discussions of particular occupations can best be given by people who have academic training for, and who have worked in, those particular occupations. You should realize, however, that it is increasingly true that the borders between various fields (e.g., between physics and chemistry, or between electrical engineering and mechanical engineering) are not sharply defined. In fact, many professional scientists and engineers work to some extent in more than one of the specialties. Many new technical fields, such as computer science and environmental science, are combinations of two or more of the traditional ones.

For several of the fields described, more detailed examples of specific types of work are included. These are intended to give a feel for what people in these fields actually do. This book attempts to provide descriptions of all the major scientific and engineering fields. *Career Opportunities in the Sciences* (see Appendix), is a listing of career brochures and other information on specific occupational fields.

Steven Walker prepares a microgravity Algal Bioassay experiment for flight in the Getaway Special Program.

Mathematics

by Valerie L. Thomas

Mathematics is the study of quantities and relations through the use of numbers and symbols. The main fields of study at the high school and college levels are arithmetic, algebra, geometry, trigonometry, pre-calculus, and calculus. Each field builds upon the one preceding it. Other subject areas include statistics, differential equations, and set theory, or abstract algebra. Mathematics is an important field in itself, but is also a very important tool in virtually all other scientific and technical occupations.

Arithmetic deals with quantities and relationships expressed by numbers, such as $2 + 3 = 5$. *Algebra* deals with quantities and relationships expressed by symbols, such as $z = x + 3y$. *Geometry* involves quantities associated with figures in space, such as triangles, rectangles, cubes, circles, and spheres. These quantities include length, area, volume, and the relationships between figures in space, such as the area of a sphere of radius R is $4\pi R^2$ and its volume is $4/3\ \pi R^3$. *Trigonometry* is concerned with the measurement of angles and the relationships of angles: for example, if we know the lengths of two sides of a right triangle we can find the remaining side and the included angles. *Pre-calculus* applies algebra and trigonometry to geometric studies. *Calculus* works with pairs of associated quantities and the way one quantity changes in relation to the other. It consists of two main subfields, differential calculus and integral calculus. For example, in differential calculus, the rate of change of position with time (or differential of position with respect to time) is velocity, and the rate of change of veloci-

Fields of Mathematics Illustrated

Algebra

John went to the school bookstore and bought six notebooks and three ballpoint pens for $15. Mary went to the same store and paid $14 for four notebooks and four ballpoint pens. What were the prices of each of the notebooks and the ballpoint pens?

Let x = price of a notebook and y = price of a ballpoint pen.

John: $6x + 3y = 15$ (Equation 1)
Mary: $4x + 4y = 14$ (Equation 2)

Solve Equation 2 for x in terms of y.

$4x = 14 - 4y$
$x = 14/4 - y$

Substitute into Equation 1, and solve for y.

$6[14/4 - y] + 3y = 21 - 6y + 3y = 21 - 3y = 15$
$3y = 21 - 15 = 6$

Therefore, y = 2. The price of a ballpoint pen is $2.

Substitute y = 2 into Equation 2 and solve for x.

$4x + 4(2) = 4x + 8 = 14$
$4x = 14 - 8 = 6$

Therefore, $x = 6/4 = 1.5$. The price of a notebook is $1.50.

Geometry

Earth is a sphere with a radius of 6378 kilometers. What is its circumference, in kilometers, its surface area in square kilometers, and its volume in cubic kilometers?

π is a constant that is equal to 3.141592

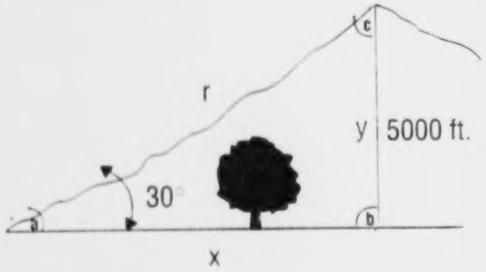
Circumference of a sphere $= 2\pi R = 2 \times 3.14159 \times 6378$ km $=$ 40,074 km.

Area of a sphere $= 4\pi R^2 = 4 \times 3.14159 \times (6378)^2$
$= 511{,}185{,}501\ \text{km}^2$
$= 5.11 \times 10^8\ \text{km}^2$

Volume of a sphere $= 4/3\pi R^3 = 4/3 \times 3.14159 \times (6378\ \text{km})^3$
$= 1.087 \times 10^{12}\ \text{km}^3$

Trigonometry

A civil engineer is planning a road that is to go up the side of a mountain. He knows that the height of the mountain is



ty, or differential of velocity, with time is acceleration. Integral calculus reverses the process: the integral of acceleration with time is the change of velocity, and the integral of velocity with time is the change of position. *Probability and statistics* is the study of the likelihood of events and is often based on large bodies of numbers. It is used for things such as scientific predictions and computing insurance company rates. For example, if you have a bag containing 10 red marbles and 90 yellow marbles, you can compute the probability of reaching into the bag blindfolded and picking out a red marble. A field of mathematics known as *Boolean algebra* is the basis of digital computer logic. Some newly emerging fields of mathematics include the studies of *fractals* and *chaos*.

As mentioned, mathematics is an essential tool in all fields of science and engineering. College curricula leading to the Bachelor of Science degree in most engineering and science fields require mathematics at least through calculus and differential equations — not only for graduation, but as prerequisites for the more advanced undergraduate courses in the specialty. For example, college-level introductory physics courses for scientists and engineers (usually taken in the freshman and sophomore years) require a knowledge of calculus.

James L. Harris is a mathematician at NASA Headquarters

In the following section, mathematics will be dealt with as an occupational specialty rather than as a tool used in other scientific and technical fields.

Types of Work

According to the United States Department of Labor, approximately 22,000 people worked as mathematicians and 15,000 as statisticians in 1990. About 73 percent of the mathematicians worked for the government or industry. The major private industry employers were aerospace, communications, machinery, and electrical equipment industries. In the federal government, the major employers of mathematicians were the Department of Defense and NASA. The statisticians worked in manufacturing (15%); federal government (27%); research and testing services (38%); and financial, insurance, and real estate (20%);

Mathematicians are involved in a variety of activities that range from the creation of new mathematical theories to the translation of scientific and management problems into mathematical terms. Mathematical work falls into two broad classes: theoretical (pure) mathematics and applied mathematics. Theoretical mathematicians advance the science by developing new principles and new relationships between existing mathematical principles. Even though this type of work is done without specific applications in mind, it has been very instrumental in producing scientific and engineering achievements.

Applied mathematicians use mathematics to develop theories, techniques, and approaches to solve practical problems. Their work ranges from analysis of the mathematical aspects of launching Earth satellites to studies of the effects of new drugs on disease.

5,000 feet above the surrounding flat land. When he reaches the foot of the mountain, he observes that the peak of the mountain is 30 degrees above horizontal. How long must the road be from where he stands to the peak of the mountain?

The length of the road, r, can be approximated by the hypotenuse of a right triangle. Using the formula $\sin a = \frac{y}{r}$, where $a = 30°$ and $y = 5000$ ft.

we find that $r = y/\sin 30° = y/0.5 = 2y = 10{,}000$ ft.

Calculus

A steel ball is dropped from a high bridge into a river. The ball takes three seconds to hit the water. If we can neglect air drag, how high is the bridge?

The acceleration of gravity is 9.8 meters/second². The velocity at any point in time $v = at$, if a is constant. Likewise, if v is constant, the distance traveled $s = vt$. However, in this case, v is not constant and so we must use integral calculus to find s as a function of t. If the acceleration a is constant,

$$s = \int_0^t v\,dt = \int_0^t at\,dt = a\int_0^t t\,dt = at^2/2$$

If $t = 3$ seconds and $a = 9.8$ m/sec², then

$$s = \frac{9.8\text{m/sec}^2\ (3\text{ sec})^2}{2}$$

$$s = 44.1 \text{ meters} = 144.7 \text{ feet.}$$

An entry-level statistician, right out of college, will generally work as a junior member of a statistical team and will spend most of the time doing fairly repetitive tasks such as organizing and categorizing data. With more experience and additional training, a statistician may become a leader of a statistical team and work more closely with company managers and government officials who have posed the problems or raised the questions to be studied by the team. At this level, the statistician will be involved in designing experiments and tests, analyzing and interpreting data, and making predictions and forecasts. Statisticians working in colleges and universities are usually involved in teaching or research. Statisticians with Ph.D. degrees often work as consultants to businesses and industry, or government agencies. Many go on to form their own consulting firms.

The statistician uses large collections of numbers to develop accurate descriptions of the characteristics of our world and its inhabitants, whether human, animal, plant, or mineral. Statistics helps all types of scientists and people at various levels of business and industry organize the facts that pertain to their work and detect the principles and trends behind the facts. Familiar examples include weather forecasting and setting insurance premium rates.

Statisticians in industry may be involved in the evaluation of products and manufacturing processes. By taking samples, statisticians can measure the reliability of a product or the efficiency of a particular process. The work of statisticians employed by the federal, state, and local governments tends to focus more on data about people and people-oriented issues (for example, Environmental Protection Agency regulation development) than on products or manufacturing processes.

Statisticians who design experiments (to be run in a laboratory or on a computer) often develop mathematical models and prepare written reports of the findings of studies. Mathematical statisticians use their knowledge of mathematical theory to design and improve statistical methods and techniques.

Educational Requirements

The minimum requirement for an entry-level mathematician in business, industry, or research is a B.S. degree with course work in calculus, differential equations, probability and statistics, and mathematical analysis. Additional course work in computer science (depending on the field in which you prefer to work) will be useful. Employers are beginning to prefer to hire mathematicians with experience and advanced degrees, which are usually required for a promotion. For those interested in a career as a mathematician in a college or university, graduate work is required, and the Ph.D. degree is almost essential.

In addition to college course work, you should consider work/study programs offered by business, industry, and government. These will provide valuable experience and insight, helping you understand the application of mathematics in the work place and giving you an appreciation for the types of courses that you should take.

High school students can prepare for a career as a mathematician by taking all of the mathematics, science, and computer courses offered in their curriculum.

For an entry-level statistician, the minimum educational requirement is a B.S. degree in statistics or mathematics. Employers frequently prefer a B.S. degree in a major field such as a natural science, social science, engineering, or economics with a minor in statistics. A statistician with an M.S. degree will advance more quickly into the financially rewarding managerial positions. For teaching and research positions at the college or university level, a Ph.D. degree is required.

Required courses for a career in statistics include mathematics (up to and including differential and integral calculus), statistical methods, and the theory of probability. Courses in computer science are strongly recommended. An ideal course of study might be a major area of concentration in statistics with a minor in computer science.

Biology

by John H. Thompson and Dr. Kathleen J. Prestwidge

Biology is the science of living things. It is concerned with their function, structure, origin, and evolution over time. Its two major divisions are *botany*, the study of plants, and *zoology*, the study of animals. However, the very simplest living organisms consist of single cells, and it often is difficult to distinguish between plants and animals at this level. Hence, the study of unicellular organisms is referred to as *microbiology*.

Humans have always been curious about the functions and structures of living things, and theories have been expounded as far back as the ancient Greeks. Major advances began during the Renaissance period, including Leeuwenhoek's 17th-century discovery of bacteria using a self-built microscope and Darwin's mid-19th-century exposition of the theory of evolution. The figure on page 12 is a representation of our current understanding of biological evolution, from the origin of life on Earth up to the modern plants and animals.

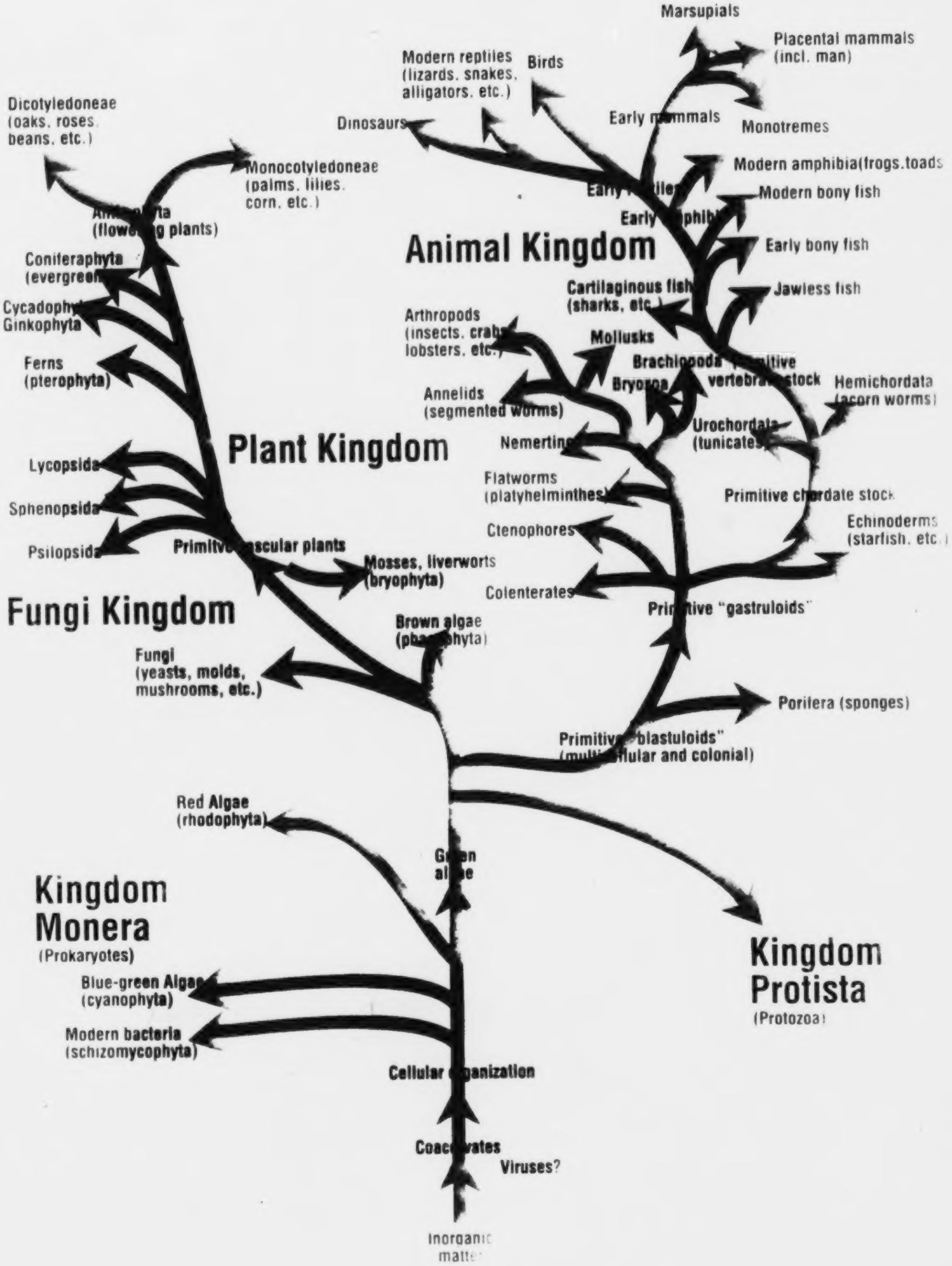
Each of the three major divisions of biology contains numerous specializations based on the particular types of organisms studied. For example, under zoology we have *entomology*, the study of insects, and *herpetology*, the study of reptiles. Under microbiology, we have *bacteriology* and *virology* as specializations. Among other subdivisions of the field of biology are *taxonomy*, the classification and naming of living things; *anatomy*, the study of the structure of living things; *physiology*, the study of the normal functions of living things; *pathology*, the study of diseases in living things; and *genetics*, the study of heredity.

Biology has major practical applications and is the basis for a number of other scientific and technical specialties. Foremost of these is *medicine*, which is of great importance to our well being. The field of medicine is extremely large and includes many related occupations such as dentistry and psychiatry. Practice in these fields requires an M.D. or similar degree, plus a period of internship at a hospital or university. Other related health professions include *nutrition*, *pharmacology*, and *toxicology*. Biology is also the basis of agriculture, the raising of food animals and the preservation and preparation of food.

Biology interacts with other scientific and technical fields, resulting in such branches as *biochemistry* (the chemistry of living organisms), *biophysics*, and *bioengineering*. The field of *ecology* is concerned with the relationships of living organisms to each other and to their environment. Biology is the basis of a field of geology concerned with the study of fossils, and of the history and evolution of life on Earth, known as *paleontology*. Biology is also involved in several other Earth science and social science fields, such as oceanography and archaeology. The field of *exobiology* is a recent branch of astronomy concerned with the search for life elsewhere than on Earth. One of the still unsolved problems of biology is concerned with the origin of life on Earth. This area of research involves biochemistry and paleontology, among other specializations, and has bearing on other areas including exobiology, genetics and evolution, and ecology.

Biochemical science is one of the many career opportunities at NASA and DOE.

Life on Earth is believed to have originated more than 3.5 billion years ago. The earliest organisms were unicellular organisms without nuclei (procaryotes), of which bacteria and blue-green algae are currently living representatives. These evolved to the more complex eucaryotes, single-celled organisms with distinct nuclei, of which green algae, fungi, and protozoa are representatives. Further evolution gave rise to multicellular organisms in two major groups (kingdoms), plants and animals. Many of the species that evolved later became extinct; for example, the dinosaurs.



Marsupials
Placental mammals (incl. man)
Modern reptiles (lizards, snakes, alligators, etc.)
Birds
Dinosaurs
Early mammals
Monotremes
Modern amphibia(frogs, toads
Early reptiles
Modern bony fish
Early amphibia
Animal Kingdom
Early bony fish
Cartilaginous fish (sharks, etc.)
Jawless fish
Arthropods (insects, crabs, lobsters, etc.)
Mollusks
Brachiopoda
Primitive vertebrate stock
Bryozoa
Hemichordata (acorn worms)
Annelids (segmented worms)
Urochordata (tunicates)
Nemertina
Flatworms (platyhelminthes)
Primitive chordate stock
Ctenophores
Echinoderms (starfish, etc.)
Colenterates
Primitive "gastruloids"
Porifera (sponges)
Primitive "blastuloids" (multicellular and colonial)
Dicotyledoneae (oaks, roses, beans, etc.)
Monocotyledoneae (palms, lilies, corn, etc.)
Anthophyta (flowering plants)
Coniferaphyta (evergreens)
Cycadophyta
Ginkophyta
Ferns (pterophyta)
Plant Kingdom
Lycopsida
Sphenopsida
Psilopsida
Primitive vascular plants
Mosses, liverworts (bryophyta)
Fungi Kingdom
Brown algae (phaeophyta)
Fungi (yeasts, molds, mushrooms, etc.)
Red Algae (rhodophyta)
Green algae
Kingdom Monera
(Prokaryotes)
Blue-green Algae (cyanophyta)
Modern bacteria (schizomycophyta)
Kingdom Protista
(Protozoa)
Cellular organization
Coacervates
Viruses?
Inorganic matter

2

Types of Work

Biologists work on land and at sea. Some work mainly in laboratories and in directing technicians, technologists, and research staff members, while others spend more time in the field, observing, taking data, and interpreting their observations. Biologists often work closely with chemists, physicists, and geologists; however, they bring essentially different perspectives to their work, and research objectives can differ considerably. By choice, theoretical biologists assimilate biological and interdisciplinary findings which requires library research and produces comprehensive overviews of many areas of study. Some of these studies, genetics for example, require a firm foundation in mathematics and statistics.

Many biologists acquire their own research grants or are employed by people with grants. They may also work for a government agency, private industry, or a nonprofit organization and become professors or teachers. Today, scientists work individually, in teams, or in teams belonging to larger divisions. A few work in isolation in the field. However, there is now more of a trend toward team projects versus the individual research that was more common in the past. There is a professional association for every large division of biological science and the health professions. Many accept members at the bachelor's degree level.

Although many of these fields may seem familiar, they are rapidly changing due to recent advances in research and applications. Therefore, job descriptions and responsibilities change quickly as well. Reading articles by scientists in current magazines and journals will help you keep up with their changing job descriptions and recent developments in the fields. The following gives more detailed descriptions of a few of the biological science and health fields.

Entomologists work in research institutions and industry. They breed insects for research and biological control; study methods of storing food and other products so they will be safe from insect damage; work in medical and veterinary medicine, agricultural organizations, and pharmaceutical houses; and serve as consultants to farmers and international organizations.

Dr. Patricia Cowings is a research physiologist at NASA's Ames Research Center. Among her activities has been research on the "space sickness" suffered by astronauts during their space flights. (NASA photograph)

Irene D. Long, M.D., does research in life sciences at NASA's Kennedy Space Center. She studies the effects of weightlessness on space travelers, including problems such as calcium loss and changes in red cell volume (NASA photograph)

Archaeology is the study of material remains of past human life. In general, archaeologists are interested in the relationship between artifacts — the objects humans made or make — and their implications regarding human behavior and evolution. Besides being engaged in research projects, archaeologists increasingly are employed by government agencies to assist in managing resources under their jurisdiction. Some archaeologists use computer analysis or apply system theories in the solution of archaeological problems.

Toxicology is the study of chemicals and drugs that can have an adverse impact on our environment and ourselves. Toxicologists determine how harmful the effects of the chemicals are and what kinds of diseases can result. Environmental toxicologists evaluate the risk of getting a disease or illness from exposure to chemicals. Forensic toxicology studies unknown circumstances that result in the death of individuals or groups; these scientists are involved with poisonings. There are clinical toxicologists as well, who monitor and determine the safe and effective dosage of drugs for many different types of patients. Industrial toxicologists are concerned with those chemicals sold on the market and the levels of them that would or might be harmful to humans, animals, and or plants.

Pharmacology is the general subject area dealing with medicines and drugs, and their beneficial and harmful effects. It is of wider scope than pharmacy, which is only concerned with the preparation and dispensing of drugs.

Pharmacology is also closely related to toxicology. Forty years ago, pharmacology was almost limited to antibiotics. Now, national interest focuses on the conquest and the prevention of many diseases with drug therapy; on the cost, safety and effectiveness of new and old drugs; and on the unresolved problems of drug and alcohol abuse. In addition, pharmacologists are concerned with pesticides, herbicides, and the toxicity and safety of industrial chemicals. Recently, pharmacologists have been concerned with the production of medicines in space (to make use of the microgravity environment) as well as the effects of drugs on people in space. Pharmacologists are needed in the field of toxicology. Other specialties include clinical, molecular, and biochemical pharmacology and chemotherapy.

Pharmacologists require M.S. or Ph.D. degrees and work in research, teaching, and health physics. Pharmacology course work is offered by schools of medicine and some schools of pharmacy. Pharmacists, such as those who work in drug stores, can find employment with only B.S. degrees. However, pharmacists also work in hospital or doctors' office settings in activities requiring more advanced degrees.

For additional information relative to other areas of Biology, consult your local library.

Educational Requirements

As is true for other fields of science and technology, preparation for a career in biology or one of the health fields requires a firm foundation in mathematics and all three basic sciences (biology, chemistry, and physics) at the high school and beginning college levels. Most biological occupations require at least four years of college, although positions as a technician or laboratory assistant may require only two years of college. Research and university teaching positions, and most medical professional occupations, require doctoral degrees.

Chemistry

by Dr. Thomas N. Cornish and Dr. Brenda S. Holmes

Chemistry is the science about substances — their composition, structure, properties, and interactions. It deals with the reactions of atoms with each other to form molecules, which are groups of atoms bound together; it also deals with reactions of molecules with each other. Chemistry is the study of the transformation of one type of material into another: for example, the combination of hydrogen and oxygen to form water, or the production of iron by decomposition of iron oxide. Chemistry is a body of knowledge that helps explain the physical world and its working. It is also practical. We apply chemical knowledge to make everyday products such as plastics, to cure diseases, and to prepare and preserve our food.

Periodic Table of the Elements

1 **H** 1.0080																	2 **He** 4.0026
3 **Li** 6.941	4 **Be** 9.0122											5 **B** 10.81	6 **C** 12.001	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.179
11 **Na** 22.9898	12 **Mg** 24.305											13 **Al** 26.9815	14 **Si** 28.086	15 **P** 30.9738	16 **S** 32.06	17 **Cl** 835.453	18 **Ar** 39.948
19 **K** 39.102	20 **Ca** 40.08	21 **Sc** 44.956	22 **Ti** 47.90	23 **V** 50.941	24 **Cr** 51.996	25 **Mn** 54.9380	26 **Fe** 55.847	27 **Co** 58.9332	28 **Ni** 58.71	29 **Cu** 63.54	30 **Zn** 65.37	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.909	36 **Kr** 83.80
37 **Rb** 85.467	38 **Sr** 87.62	39 **Y** 88.906	40 **Zr** 91.22	41 **Nb** 92.906	42 **Mo** 95.94	43 **Tc** (99)	44 **Ru** 101.07	45 **Rh** 102.906	46 **Pd** 106.4	47 **Ag** 107.870	48 **Cd** 112.40	49 **In** 114.82	50 **Sn** 118.69	51 **Sb** 121.75	52 **Te** 127.60	53 **I** 126.9045	54 **Xe** 131.30
55 **Cs** 132.906	56 **Ba** 137.34	57 **La** 138.906	72 **Hf** 178.49	73 **Ta** 180.948	74 **W** 183.85	75 **Re** 186.2	76 **Os** 190.2	77 **Ir** 192.2	78 **Pt** 195.09	79 **Au** 196.967	80 **Hg** 200.59	81 **Tl** 204.37	82 **Pb** 207.2	83 **Bi** 208.981	84 **Po** (210)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac** (227)	104 **Rf** (261)	105 **Ha** (262)													

58 **Ce** 140.12	59 **Pr** 140.908	60 **Nd** 144.24	61 **Pm** (147)	62 **Sm** 150.4	63 **Eu** 151.96	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.930	68 **Er** 167.26	69 **Tm** 168.934	70 **Yb** 173.04	71 **Lu** 174.97
90 **Th** (232)	91 **Pa** (231)	92 **U** (238)	93 **Np** (237)	94 **Pu** (242)	95 **Am** (243)	96 **Cm** (248)	97 **Bk** (249)	89 **Cf** (249)	99 **Es** (254)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)

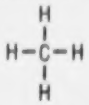
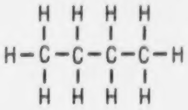
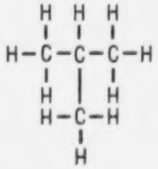
The periodic table of the elements is of fundamental importance to both chemists and physicists. It arranges the known chemical elements according to increasing atomic number, that is, the number of protons in the nucleus (equal to the number of electrons surrounding the nucleus) of each atom (indicated above the symbol in each box). The atomic weight, below the symbol in each box, is approximately equal to the number of protons and neutrons in the nucleus of each atom. Chemists have found that elements in groups making up the vertical columns of the periodic table have chemical properties that are similar to each other.

Chemistry plays such an important role in our lives that everyone should have some knowledge of it. The field of chemistry also offers many opportunities for a challenging and lucrative occupation. It offers a variety of employment possibilities such as in industries producing textiles, rubber, glass, polymers, pharmaceuticals, electronics, paper, packing, machinery, fuels, and food.

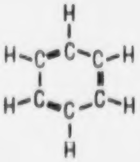
The study of chemistry has made many important contributions to modern life. To highlight how fascinating a career in chemistry can be, a few areas of this field are mentioned. In recent years, chemistry has given us new materials to make clothes easier to care for (polyester fabric) and to make automobiles lighter and thus more economical (thermoplastics). In health, chemistry has attacked the problem of fighting disease and keeping people healthy in many ways. By studying the chemical processes that take place in the normal and diseased bodies, it has been possible to learn much about these processes and to devise ways of controlling them. Chemistry has been particularly helpful in discovering how the human body uses food and what foods are necessary for health. The whole problem of treating disease by means of drugs is called chemotherapy. It has produced important medicines such as the sulfa drugs and has helped also in the purification of penicillin and the third- and fourth-generation antibiotics.

Chemistry has increased the sources from which a person can obtain energy. High-powered gasoline is obtained from crude oil (or, more recently, even from coal or oil shale) by chemical processes. Automobile storage batteries resulted from research in electrochemistry; a current field of development is advanced storage batteries and fuel cells for electrically powered automobiles and for aerospace

The chemical symbols for compounds can be shown in different ways to illustrate their contents of various types of atoms and also to illustrate the structures of the molecules. Examples are shown below:

Name of Compound	*Formula*	*Structural Formula**
Methane	CH_4	 $\begin{array}{c} H \\ \vert \\ H-C-H \\ \vert \\ H \end{array}$
Acetylene	C_2H_2	$H-C\equiv C-H$
Butane	C_4H_{10}	 $\begin{array}{c} H\ \ H\ \ H\ \ H \\ H-C-C-C-C-H \\ H\ \ H\ \ H\ \ H \end{array}$
Isobutane	C_4H_{10}	

Note that butane and isobutane have the same chemical formula, but different molecular structures.

Benzene	C_6H_6	

*— = single bond, =double bond, ≡triple bond

applications. The fluorescent light bulb resulted from investigations of the various chemical compounds that could successfully be used to produce light at the least cost. Chemists are helping to produce energy by developing the alcohol obtained from plants into an important source of fuel.

Chemistry includes the five major subfields of study described below:

Organic chemistry deals with the preparation, reactions, and properties of both natural and synthetic carbon compounds. It is a major subfield because carbon forms a much greater variety of compounds than any other single element. Many of these compounds are found in living organisms, hence the name organic chemistry, but many can also be produced by nonbiological processes. Some of the subdivisions of organic chemistry include the study of macromolecules (polymers), biochemical processes, and molecular biology, since these fields involve carbon compounds to a great extent.

Inorganic chemistry deals with the preparation, reactions, and properties of both natural and synthetic compounds of all the known elements other than carbon. Inorganic and organic chemistry overlap in the area of organometallic compounds.

Physical chemistry deals with the study of matter as it relates to the laws of physics. It involves subfields such as thermodynamics, kinetics, and quantum mechanics, particularly as they relate to chemical reactions and the struc-

Chemical and Physical Reactions

The various forms of matter can react with each other or by themselves, with input or output of energy. In chemistry, reactions involving molecules and atoms maintain the same numbers of each type of atom, before and after the reaction; for example:

Burning of Natural Gas

$$\underset{\text{(methane)}}{CH_4} + \underset{\text{(oxygen)}}{2O_2} \rightarrow \underset{\text{(carbon dioxide)}}{CO_2} + \underset{\text{(water)}}{2H_2O} + \text{heat}$$

Use of Hydrazine as a Rocket Propellant

$$\underset{\text{(hydrazine)}}{N_2H_4} \rightarrow \underset{\text{(nitrogen)}}{N_2} + \underset{\text{(hydrogen)}}{2H_2} + \text{heat}$$

Green Plant Photosynthesis

$$CO_2 + H_2O + \text{energy} \rightarrow CH_2O + O_2$$

(CH_2O is a basic molecular component of carbohydrates such as starch and sugar.)

At the subatomic scale, physicists write similar equations for the reactions between elementary particles and atomic nuclei. For example:

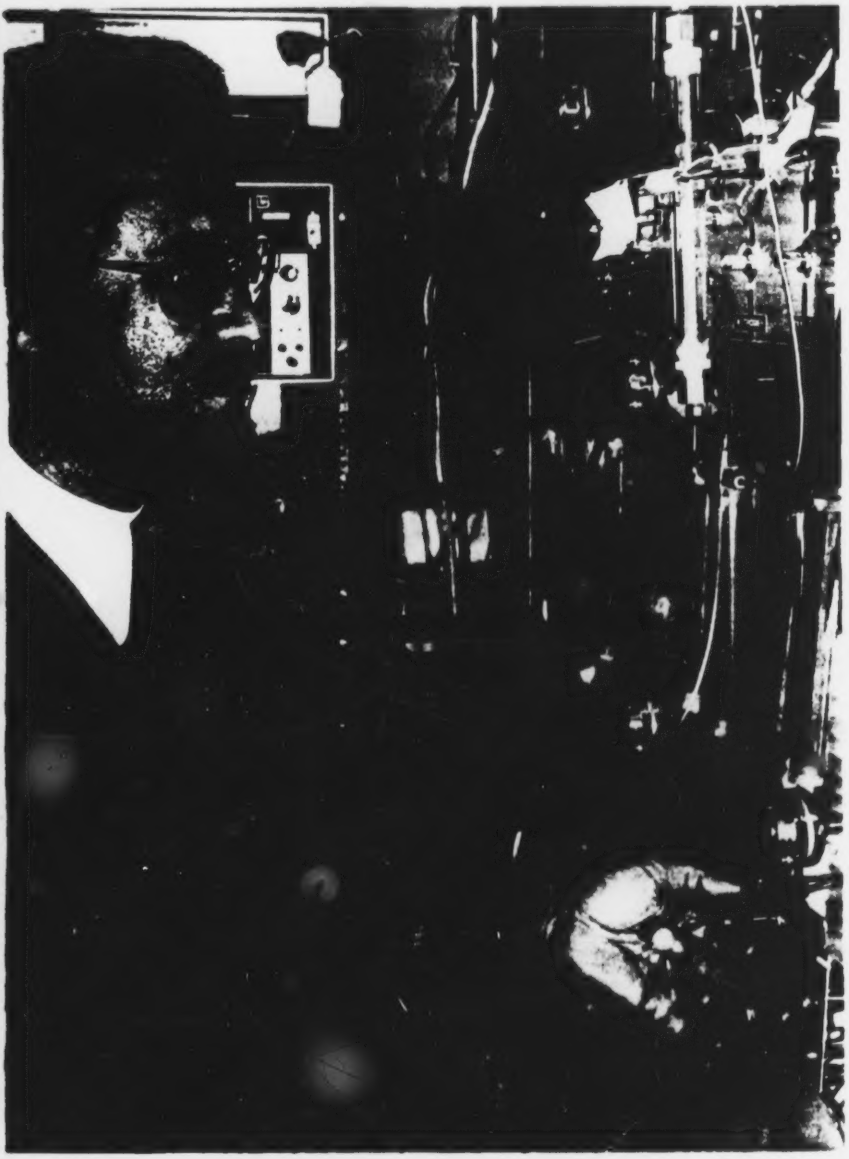
Uranium Fission*:

$$\underset{\text{(Uranium-235)}}{{}_{92}U^{235}} + \underset{\text{(neutron)}}{n} \rightarrow \underset{\text{(Strontium-90)}}{{}_{38}Sr^{90}} + \underset{\text{(Xenon-136)}}{{}_{54}Xe^{136}} + \underset{\text{(neutrons)}}{10n} + \text{energy}$$

Radioactive Decay:

$$\underset{\text{(radium)}}{{}_{88}Ra^{226}} \rightarrow \underset{\text{(radon)}}{{}_{86}Rn^{222}} + \underset{\text{(helium nucleus = alpha particle)}}{{}_{2}He^{4}} + \text{energy}$$

*In ${}_{92}U^{235}$, the 92 indicates the number of protons (positively charged particles) in the nucleus of the atom (the atomic number), whereas the 235 indicates the total number of protons and neutrons (uncharged particles) in the nucleus (the atomic weight).



Harold G. Eaton, an analytical research chemist at the Naval Research Laboratory, is shown adjusting flow rates of various gases going into a reacting chamber (not shown). The instrumentation shown here is used to study the efficiency of decomposition of dimethyl methylphosphonate vapor from a helium stream in an atmospheric pressure, alternating current capacitive discharge system. The overall impact of this study was to understand better the chemistry of electric discharges as air purification systems. (NRL photograph)

tures of molecules. There is considerable overlap between chemistry and physics in this subfield.

Analytical chemistry deals with determining the composition of materials and measuring exact quantities of materials as well as separating materials into their basic components. Analytical chemistry involves the use of many instruments to measure these quantities precisely.

Biochemistry deals with the chemistry of living systems, or the reactions and processes that occur in the cells of plants and animals. Biochemistry overlaps with organic chemistry, in that it includes the study of organic compounds and macromolecules that occur within our bodies and other living organisms.

Types of Work

Employment opportunities for chemists exist in government, private industry, military, and medical sciences. Industry affords an excellent slot for new product research, such as the plastics, new antibiotics, new paints, and fabric modification to increase wear and to deter wrinkling. Government chemists are involved in interesting assignments that include environmental problems (water purification by chemical means, analysis of the atmosphere for pollutants, etc.), testing materials for fire resistance potency (quality control), and synthesizing and formulating hydraulic fluids resistant to sea water. The jobs that chemists perform are endless.

Chemists often work very closely with physicists, chemical engineers, biologists, pharmacists, and medical personnel. One of the most significant projects developed from such collaboration is the technique called Medical Imaging, which is a noninvasive, nondestructive method of detecting tumors and malignant cells in human beings, and which may eventually replace harmful X-ray techniques.

Chemistry has a very close relationship to several other professions, including chemical engineering, medicine, and pharmacy. They are so closely related that the first two years of college-level training are nearly identical. It is very easy to switch from one to the other before the junior year. All three fields require a heavy background in chemistry.

Some students go directly to medical school after they receive the B.S. degree in chemistry. Physical chemistry is closely related to physics, particularly atomic, molecular, and solid-state physics. Chemistry is an important part of the Earth and space sciences in the areas of atmospheric chemistry, astrochemistry, geochemistry, and environmental science.

Educational Requirements

You should start preparing for a career in chemistry as early as junior high school by pursuing courses in mathematics, science, and English. A college-preparatory schedule should be followed in high school to prepare for a chemistry major in college. College curricula leading to a B.S. degree in chemistry will include general liberal arts requirements in addition to courses in general, organic, physical, and analytical chemistry. Many colleges include courses in biochemistry, inorganic chemistry, and polymer chemistry in the undergraduate curricula. Those individuals who wish to pursue research careers in chemistry will most likely attend graduate school for advanced degrees where their areas of study will be more concentrated.

Common subjects elected as minors by chemistry majors are mathematics, computer science, physics, biology, and chemical engineering. Courses in computers and computer programming, probability and statistics, chemical engineering, economics, organizational behavior, and management may be good electives.

Chemical engineering majors are required to study mathematics through differential equations and to have some experience with computers. A one-year course in physics and at least six semesters of chemistry are required. If possible, a few elective courses in science and mathematics are recommended.

Engineering courses will also be required in each semester. Typical topics are heat and mass transfer, thermodynamics, fluid dynamics, process engineering, and chemical engineering design.

Pictured is Dr. Brenda Swann Holmes, research chemist at the Naval Research Laboratory in Washington, D.C. She is shown at the console of a JEOL FX-60Q nuclear magnetic resonance spectrometer (magnet in background) where she is preparing to record a spectrum on paper which was stored earlier on cassette tape. (NRL photograph)

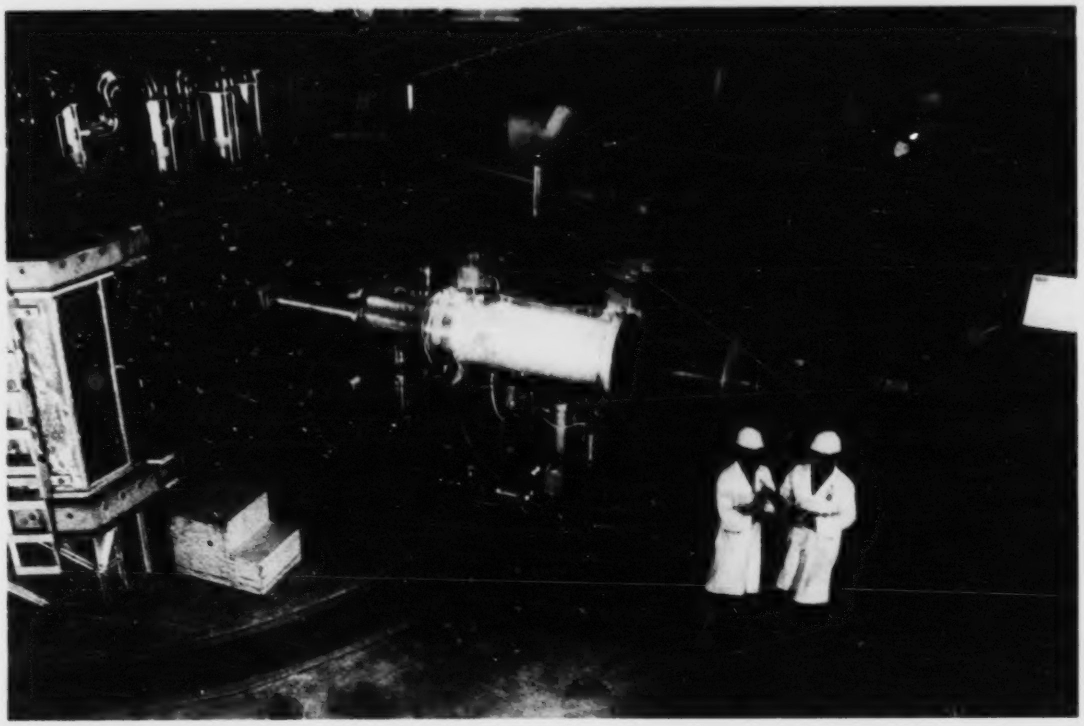
Physics

by Dr. George R. Carruthers

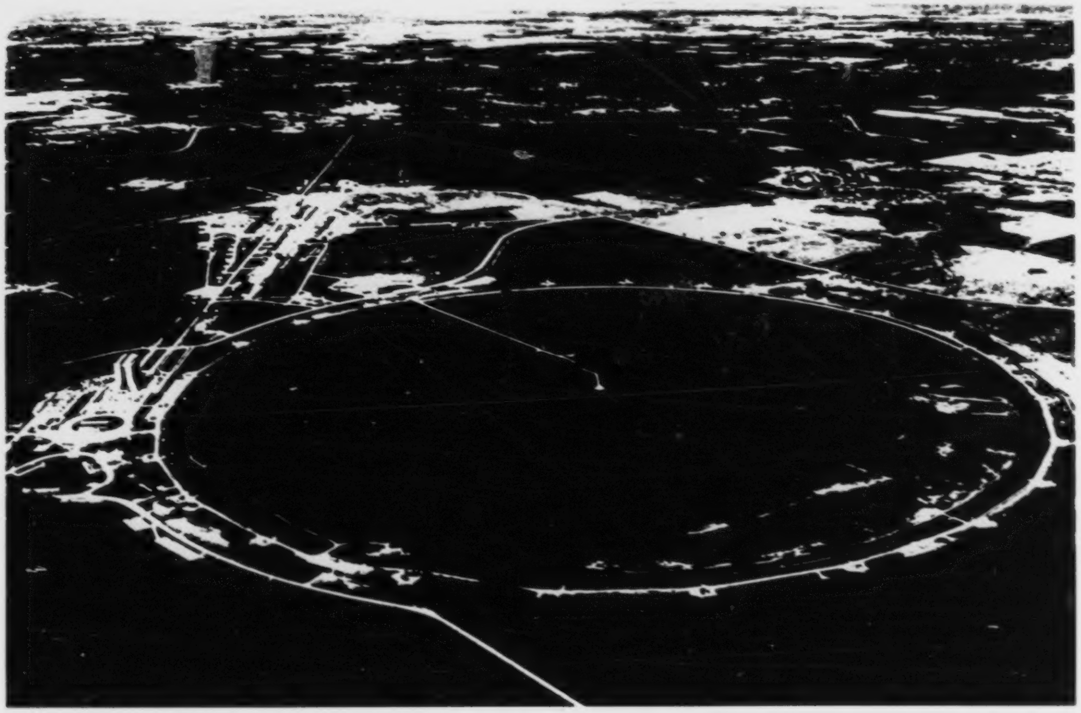
Physics may be defined in broad terms as the study of nature — all natural phenomena not covered by biology and chemistry. More specifically it may be defined as the study of matter, energy, and their interactions. This includes the studies of: force and motion (*mechanics*), sound (*acoustics*), heat (*thermodynamics*), electricity and magnetism, and of light (*optics*). It also includes the study of matter on a submicroscopic scale — atomic physics, nuclear physics, molecular physics, and solid-state physics.

There is no sharp dividing line between the fields of physics, biology and chemistry, as is shown by the existence of such subfields as biophysics and physical chemistry. However, chemistry emphasizes the *reactions* between various atoms and molecules whereas physics emphasizes the *properties* of the atoms and molecules, the elementary particles (electrons, protons, and neutrons) that make them up, and their interactions with energy. Nuclear physics and particle physics deal with the nuclei of atoms and their reactions with each other and with elementary particles, and in this respect are similar to chemistry but on a smaller scale of the structure of matter.

To make further progress in defining the extremely broad field of physics, some of its major subfields must be described. These are sometimes grouped into two broad categories, classical physics and modern physics. The former includes the subfields of mechanics, acoustics, thermodynamics, electromagnetism, and optics; essentially, those fields of physics which were reasonably well understood at the beginning of the 20th century. Modern physics includes atomic, nuclear, and particle physics; these fields were relatively undeveloped before the advent of the theories of relativity and quantum mechanics, which also are major fields of modern physics and form the basis for the other three just mentioned. Classical physics is primarily a foundation of knowledge used in engineering and less a field of basic research, whereas modern physics is primarily an area of basic research and less an area of applications. However, this obviously is not a hard and fast rule; there are still many basic research activities in classical fields such as optics, and nuclear engineering is an example of applied modern physics.



This modified betatron is used by the Plasma Physics Division of the Naval Research Laboratory. It can accelerate electrons to 50 million electron volts of energy with currents as high as several thousand amperes. Its current use is in studying the critical physics issues of high current, recirculating accelerators, including injection and extraction. It may also provide useful information in the design of compact accelerators for military applications in directed energy systems. (NRL photograph)



An aerial view of the Fermi National Accelerator Laboratory, in Batavia, Illinois. It is used to accelerate elementary particles to extremely high energies, primarily for the study of the structure of matter at subatomic scales. The large circle, about a mile across, marks the location of the main accelerator ring, located underground. The straight line tangent to the ring at the left marks the location of one of the experimental test lines. The 16-story twin-towered Wilson Hall is seen at the base of the experimental line. (Fermilab photograph)

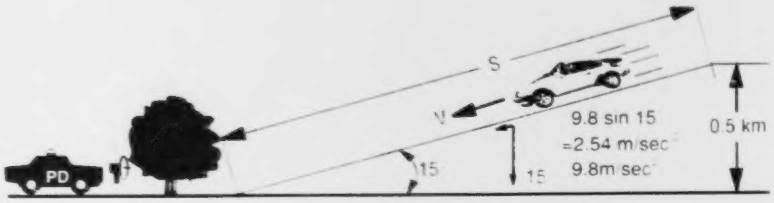
Mechanics deals with the properties of materials and their interactions with external forces; for example, it determines the trajectory of a moving object in a gravitational field, or the force exerted on an airplane wing as it moves through the air. Acoustics deals with the production and propagation of sound waves. Thermodynamics deals with heat, its propagation, and its effects on gases and other materials. It is the basis for energy production by a gasoline engine, for example. Electromagnetism forms the basis of the major field of electrical engineering, and deals with the properties and interactions of electrically charged particles and of electric and magnetic fields. Optics deals with the properties and propagation of electromagnetic radiation, which includes visible light, and of material objects such as lenses, mirrors, and photoelectric cells which interact with electromagnetic radiation.

Modern physics, as mentioned, is based on the subfields of relativity and quantum mechanics. These fields, which did not exist before the early 20th century, are essential to the understanding of matter and energy at the molecular and atomic level (and smaller). They also are essential to a proper understanding of the generation, propagation, and interactions of electromagnetic radiation. Relativity is a modification of the laws of classical physics which, for example, is important when material objects travel at speeds approaching the speed of light. It also states the equivalence of matter and energy, through the famous equation $E=mc^2$. Quantum mechanics, on the other hand, is a modification of classical mechanics, which is important at very small size scales, such as those of atoms and molecules. The motion of Earth around the Sun can be described by classical mechanics, but the interactions of electrons and protons in an atom require quantum mechanics for accurate description.

Principles of Physics Illustrated

The principles of physics enter all aspects of our daily lives.

A car is at the top of a hill 0.5 kilometer high, with a 15 degree slope. If the driver decides to go for a joy ride by releasing the brakes and coasting downhill, how long will it take to reach the bottom, and how fast will he be going when he gets to the bottom?



The acceleration of gravity is 9.8 meters/sec^2, but acts only downward, not parallel to Earth's surface. Therefore, the component of acceleration that is effective is that which is parallel to the road:

$$a_{parallel} = a \sin 15° = (9.8) \sin 15° = 2.54 \text{ m/sec}^2.$$

The velocity $v = at$ and the distance downhill, $s = \int v dt = at^2/2$. But we know the distance downhill, s, is 0.5 km / sin 15° = 0.5/0.259 = 1.932 km = 1932 meters.

Therefore, $t^2 = (2)(1932)/2.54 = 1521 \rightarrow t = 39$ seconds and hence $v = at = (2.54)(39) = 99$ m/sec = 221 mph.

Of course, air drag and wheel friction will reduce this somewhat. Note that this velocity is actually independent of the slope angle, and is the same as if the car dropped vertically 0.5 kilometer.

A farmer is shopping for an electric motor to use for a water pump at his well, located 200 feet from his house. He has #16 electric wiring between his house and the well. The salesman suggests a 1-horsepower motor, with options of 115 volt or 230 volt operation. Which is better, and why?

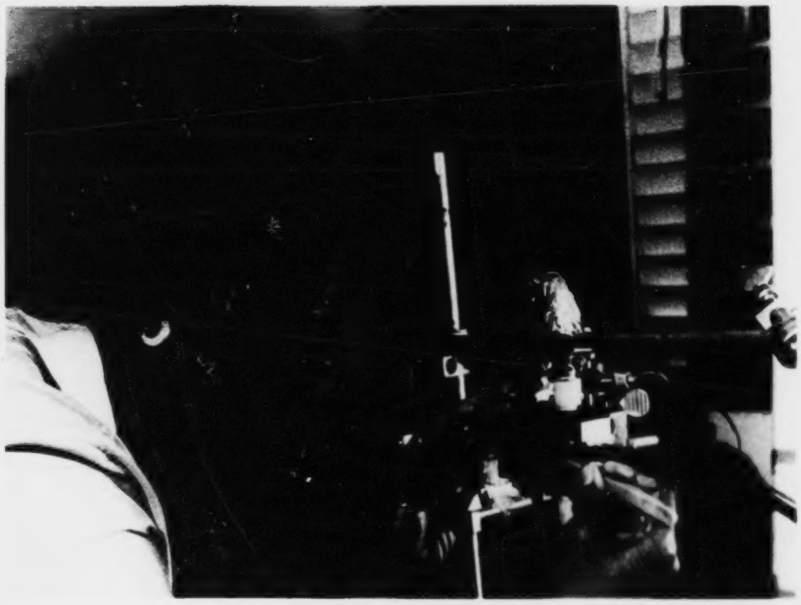
A 1-horsepower motor requires about 1000 watts of electric power, regardless of operating voltage. However, current and voltage are inversely related by the relation

Power(Watts) = Current(amperes) x Voltage(volts) =
Voltage/Resistance(ohms) x Voltage =
(current)^2 x resistance

$$P = IV = V^2/R = I^2R$$

Therefore, a 1000-watt load requires 8.7 amperes at 115 volts, or 4.35 amperes at 230 volts. However, power is also lost in the resistance of the lines leading to the motor. 400 feet of #16 copper wire having a typical resistance of 4 ohms per 1000 feet (total 1.6 ohms). Therefore, the 115-volt motor would incur an additional 1.6 ohms x (8.7 amperes)^2 = 121 watts loss in the line, whereas the 230-volt motor would incur only $(1.6)(4.35)^2 = 30$ watts of line loss. Note that with the 115-volt motor, the actual voltage drop in the line is $V = IR = 14$ volts, leaving only 101 volts for the motor (if the current stays at 8.7 amperes), so it will not perform as well as required. Alternately, one would have to provide an input line voltage at 129 volts to have 115 volts at the motor.

This example illustrates why high voltages are used for transmitting large amounts of electric power over long distances.



Mrs. Delores H. Walker, a research physicist at the Naval Research Laboratory, is mounting a prototype solar cell on a water-cooled block that will maintain the temperature of the solar cell at a fixed temperature during measurements. The solar cell will be illuminated with light comparable to sunlight and evaluated for its resistance to damage from nuclear radiation. (NRL photograph)

Dr. William E. Howell is shown operating a pair of missile-like infrared sensors to check the emission quality of an exotic decoy material that produces its own heat on contact with air. Dr. Howell's work at the Naval Research Laboratory, where he holds positions as a research physicist and section head, includes the exploratory development of new materials and techniques for improving the Fleet's decoy capability against heat-seeking and radar-guided missiles. As team leader on the development of several new decoy concepts, his work ranges from basic research through hardware design and prototyping, to testing at sea in scenarios that simulate combat. (NRL photograph)

At the molecular level, there is significant overlap between modern physics and chemistry; quantum mechanics is a necessary basis for understanding chemical reactions. Solid-state physics deals with the properties of multi-atom structures (crystals) and the propagation of electric charges and electromagnetic radiation in them.

Other closely related fields of physical science include astronomy, geology, and meteorology. These fields are all based on physics as a foundation of knowledge, used to explore the nature of the objects under study. For example, astronomy (particularly those areas known collectively as astrophysics) makes use of optics, electromagnetism, and modern physics to determine the composition, temperature, and pressure of gaseous and solid materials in celestial objects. Planetary sciences, including geology and meteorology, use physical (and chemical) knowledge to study the nature of Earth, other planets, and their atmospheres.

Some examples of major recent discoveries in physics include discovery that the proton and neutron, previously thought to be elementary particles, are themselves made up of smaller entities (known as quarks); discovery and development of the maser and laser; and advances in the understanding of the properties of ionized gases (plasmas), which may lead to controlled thermonuclear (fusion) reactions and their use as a practical energy source. These also are still current areas of basic research in physics. It is interesting to note that to explore the structure of matter on smaller and smaller scales, higher and higher energies are needed in particle accelerators and other equipment used in the research. Therefore, larger and more powerful tools are needed to study smaller components of matter.

Educational Requirements and Types of Work

As mentioned above, physics is the foundation for most of the engineering fields. Therefore, a person with a B.S. degree in physics can often find employment in engineering fields or in related fields of the physical sciences, such as the Earth and space sciences. Many colleges offer degrees in engineering physics for those planning to apply their knowledge of physics to practical problems. However, basic research in physics and related fields usually require the Ph.D. degree, as does the teaching of physics at the college or university level.

It is extremely important for those interested in careers in physics to obtain a firm basis in mathematics and science as early as possible. You should take, and do as well as possible in, all of the mathematics and science courses available in high school. If the available courses do not include mathematics through trigonometry and pre-calculus, and both chemistry and physics, it may be necessary to take remedial courses between high school and college.

The beginning college curriculum of a physics major includes calculus, differential equations, and more advanced mathematics courses, as well as college chemistry and college physics. The latter covers all of the major fields of physics, as does high school physics, but requires and uses calculus. Later physics courses cover individual subfields such as mechanics, optics, electricity and magnetism, and quantum mechanics. These usually have more advanced mathematics prerequisites. Depending on your particular interests, electives can be taken in other fields, such as chemistry, electrical engineering, geology, or astronomy.

Physicists are employed in industry, government, and universities. At the Ph.D. level, they may do basic research on such things as the structure of subatomic particles, superconductivity, and properties of semiconductors. At the M.S. and B.S. levels, they may assist Ph.D. researchers, or they may be employed in more applied tasks such as the development of particle accelerators, free electron lasers, and electronic imaging devices. Because of the breadth of their training, physicists have more flexibility in career selection and change than those who are trained in more specialized science or engineering fields.

Earth Science

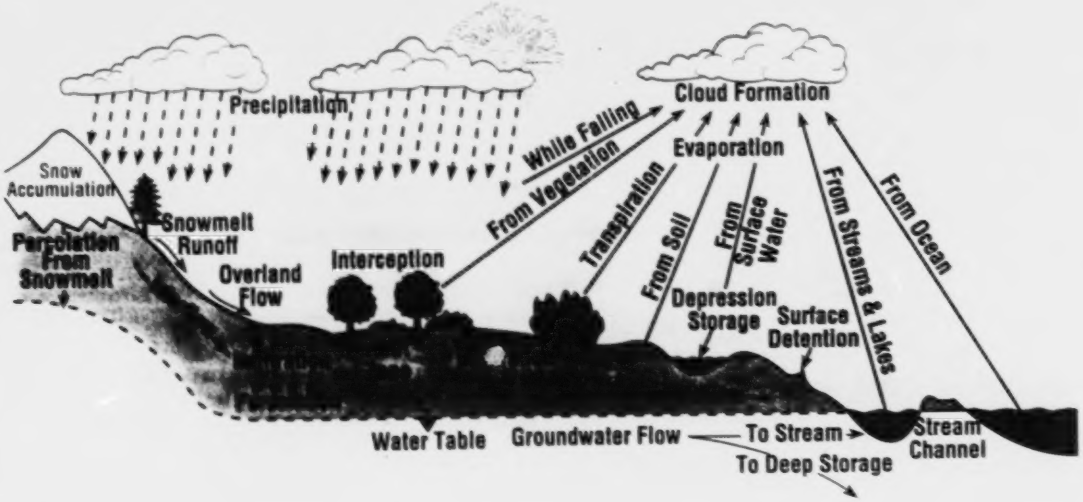
by Marilyn J. Suiter

Geoscience, or Earth science, is a collective term for the scientific disciplines that involve the study of our planet Earth. It focuses on the study of the materials of which Earth is made, the processes that act on these materials, the products formed, and the history of the planet and its life forms since its origin. Energy resources, water availability and quality, and earthquake activity are some of the topics in geoscience that are familiar to most people.

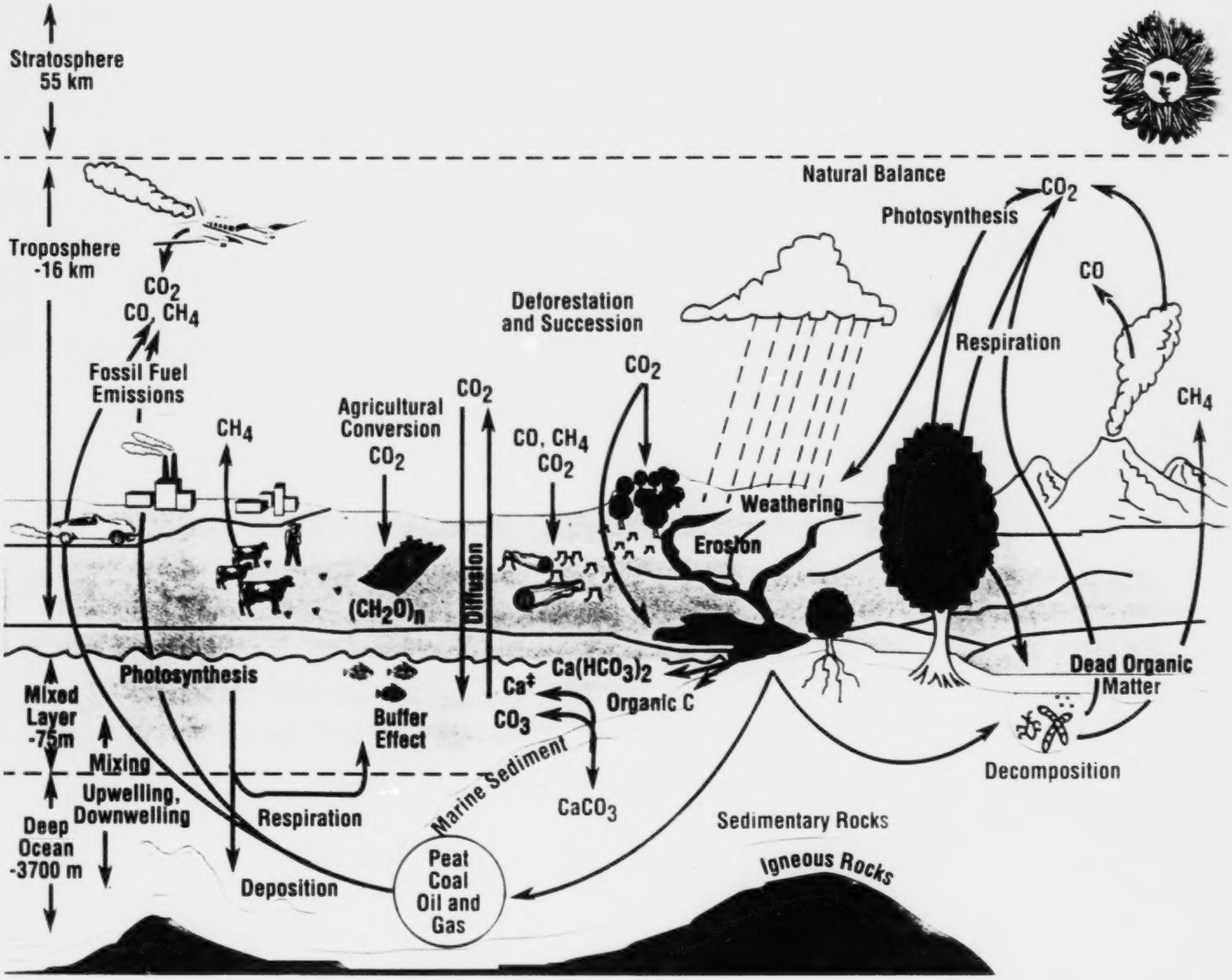
Earth science disciplines include *geology* (the study of the Earth) as a major field, with various subfields or related fields as specialties. These include *oceanography*, *meteorology* and other atmospheric sciences, *environmental science*, and *ecology*. Specializations within geology that interface with other basic science areas include *geophysics* and *geochemistry*. *Planetology* and *planetary science* apply geologic principles to other planets in our solar system. *Engineering geology* deals with the practical applications of geology, such as to the mining and the petroleum industries.

Many scientists and technicians who have chosen Earth science as a career enjoy it because of the opportunities to work outdoors, the challenge of solving problems that are multifaceted, and the interaction of many sciences (such as chemistry, biology, and physics) in real-life applications. The growing interest in energy resources and in the protection and restoration of our environment has contributed to increased interest in the Earth sciences.

Careers in the Earth sciences embrace a wide range of employment areas. Research, education (both precollege and higher education), government agencies, and private industry are all included. Careers sometimes overlap; for example, a college professor usually pursues research interests in addition to teaching. There is also overlap among disciplines; a geologist in the petroleum industry may use geology, geophysics, geochemistry, and engineering geology.



The hydrologic cycle is one of several planet-wide cycles that affects Earth's environment. As shown, water is continuously cycled between gaseous, liquid, and solid forms and has major interactions with the solid Earth and with vegetation. It is important for us to obtain a better understanding of the details of this cycle, and factors affecting us, to avoid major problems such as droughts and flooding. (NASA illustration)



The carbon cycle is another biogeochemical cycle of great practical importance. It establishes the balance of carbon in its various forms, including fossil fuels at one end, and carbon dioxide and carbonates at the other. Note that energy from the Sun, geological processes, and artificial activities have major effects on this cycle. (NASA illustration)

Current and Near-Future Prospects

Geoscience employment, as mentioned above, can be found in a wide variety of businesses and public organizations. The petroleum industry is the major employer of geoscientists (about 50 percent); state and federal government agencies are the next largest (about 12 percent), followed by education (7 percent).

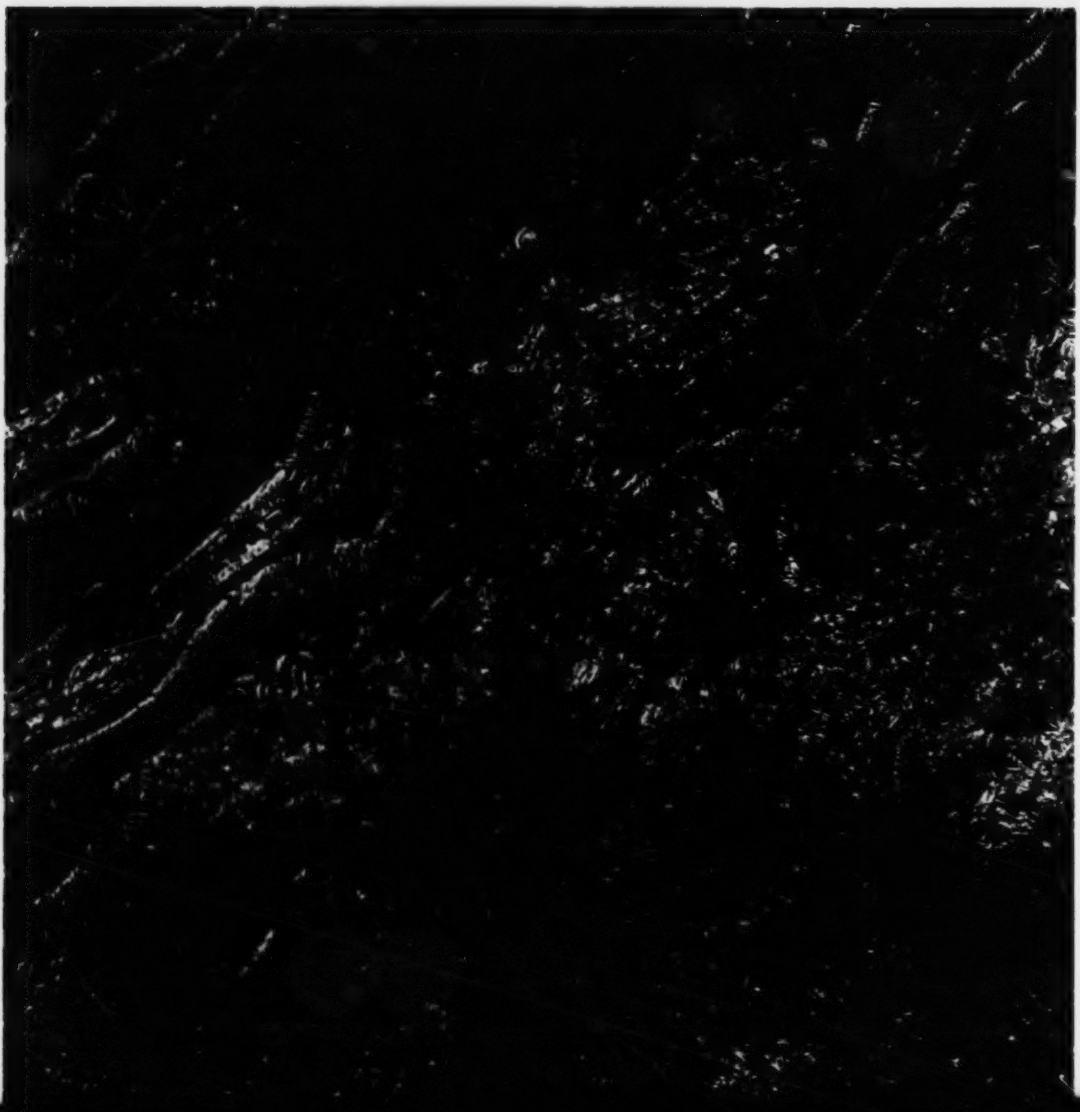
Although recent international economic problems have caused the United States petroleum industry to suffer losses, projections for that industry are encouraging. The domestic (United States) petroleum industry is focusing on improving the production from established oil and gas fields and doing less exploration (discovery of new fields). Foreign efforts in exploration are still active, although at a lower level than in the early 1980s.

The fastest growing geoscience careers are those that involve the protection and restoration of the environment: areas such as water quality and hazardous waste. Water, one of our most valuable resources, poses two major concerns: availability and quality. Availability of water is a major issue for land planners and farmers. It is also important that the water is of high quality and be free of contaminants. The mapping of water bodies, both on Earth's surface (lakes, rivers, oceans) and in the subsurface (ground-water aquifers) is a geoscience specialty called *hydrology* (or hydrogeology).

Hazardous waste is a subject of increasing concern for most citizens. The release of waste materials, whether solid, liquid or gaseous, presents the potential hazard of contaminating the body into which it is deposited: the air, rivers and streams, or the soil. Geoscientists work to predict probable contamination in subsurface conditions (such as by leakage from storage drums containing waste materials) and to correct contamination accidents. The employers in these areas are most frequently consulting firms; state agencies and national laboratories are other potential employers.

Earth scientists make increasing use of air- and space-based vehicles, and advanced undersea submersible vehicles, to expedite their studies. They may, for example, be involved in major space programs such as Landsat and the planned Earth Observing System.

Planetary science is another area of increased interest. The exploration of space is a multi-national endeavor and is pursued by many commercial/private-sector groups as well. Geoscientists contribute during the planning of missions and by analyzing the materials collected from extraterrestrial/planetary bodies to determine composition. This can have particular significance for economic geologists and the mining industry. Other geoscience activities include mapping and interpreting photographs of these extraterrestrial bodies.



An image of the region near Roanoke, Virginia (blue area, just below center), obtained with a NASA Landsat satellite. This false-color image shows the distributions of many features of interest to Earth scientists. These include important surface materials as revealed by their distinctive coloration, such as vegetation (shown here pink); geologic features such as mountains, lakes and river beds; and man-made features such as roads, buildings, and farmland. (NASA photograph)

The teaching of Earth science, particularly at the precollege level, is also becoming more popular. This is partly in response to increased national interest in a variety of Earth science issues, including natural hazards such as earthquakes, volcanic eruptions, flooding, and radon gas emissions. In addition, sharing your knowledge and enthusiasm for science with young people can be a satisfying career and one that is of great importance to our nation.

Salaries in the Earth sciences vary depending on the economic market for a particular field and an individual's qualifications, including academic degree.

Educational Requirements

A high school student interested in studying Earth science in college needs to have a good background in mathematics and science. In addition, it is beneficial to learn communication skills, both in writing and in speaking. It is also important to learn computer science, as computers are an essential part of most activities in science and technology.

A college program in geoscience further develops your general knowledge of science and mathematics, but usually also includes courses in geology, mineralogy/crystallography, sedimentary geology, petrology, historical geology/paleontology, field geology, and laboratory courses. Some institutions offer independent study courses that provide an excellent opportunity to develop research skills and professionalism.

Although the bachelor's degree is sufficient to gain employment in some situations, the American Geological Institute's employment survey indicates that more than 60 percent of those hired in 1989 have a master's degree. A master's degree program provides a combination of more advanced course work and usually independent research. Many employers feel that these factors better equip an employee to be a productive member of a professional staff.

The geoscience discipline selected most often for an undergraduate degree is general geology or Earth science, followed by petroleum engineering and geophysics. At the graduate level, most master's degrees are in geophysics, followed by general geology/Earth science and petroleum engineering. Most doctoral degrees are in geophysics, followed by economic/mining geology and petroleum engineering.

Description of What a Geoscientist Does

The on-the-job activities of many geoscientists have been described earlier in this section. Generally, the duties of Earth scientists include gathering information or data to define clearly a subject of geoscientific interest. This may be an area of land (on or below Earth's surface), or in the ocean, the atmosphere, or in space. The information is then analyzed to provide an initial answer to whatever problem is being investigated. After testing this initial answer, the Earth scientist may share the resulting conclusions with other Earth scientists to determine the next action.

For example, in the petroleum industry a geoscientist collects data about layers of rocks in the subsurface. This information may help the petroleum geologist to determine if the rock contains oil or gas. If that seems likely, the petroleum company may decide to drill a well into that layer of rock to test for the presence of oil and/or gas. The geoscientist may go to the drilling location to supervise the drilling operation and to provide technical reports on the activity. Drilling locations vary from those commonly identified with this industry, such as the oil fields of Texas and Oklahoma, to more exotic locations such as the North Sea and the Brazilian rain forest. A successful venture results in profits for the company and energy resources for the customer.

A geoscientist working for the government may study a variety of issues that are important to the public, from local land-planning needs to the updating of topographic maps, and other research topics.

The following are brief descriptions of some other geoscience specializations. A *geochemist* analyzes the composition of Earth materials. A *geophysicist* uses quantitative methods to study the physical properties of Earth. (Seismology and tectonics are two areas addressed by geophysicists.) An *engineering geologist* uses geoscientific data and techniques to assure that the engineering aspects of construction (buildings, dams) include proper treatment of geologic factors. An *economic geologist* studies geologic materials used commercially, such as fuels, metals, nonmetallic minerals, and other Earth resources. This includes the search for and identification of deposits of such materials. A *geomorphologist* studies Earth's surface, specifically to describe landforms and examine their developmental history. A *paleontologist* studies the chronology of Earth's history based on fossil plants and animals. An *oceanographer* studies the marine environment of the ocean, including its physical, chemical, biologic and geologic aspects. A *meteorologist* works in the atmospheric sciences and is concerned with Earth's lower atmosphere, specifically including weather phenomena.

Summary

The geosciences present many exciting challenges. Those who enjoy solving problems, observing and classifying Earth materials, and working in and on a variety of geographic locations will find the geosciences an appropriate career choice. Additional information on topics in geoscience can be found at a local library, through municipal, state, and federal science agencies, and through professional geoscience organizations such as the American Geological Institute.

Meteorology

by Renee R. Fair and Edward H. Young, Jr.

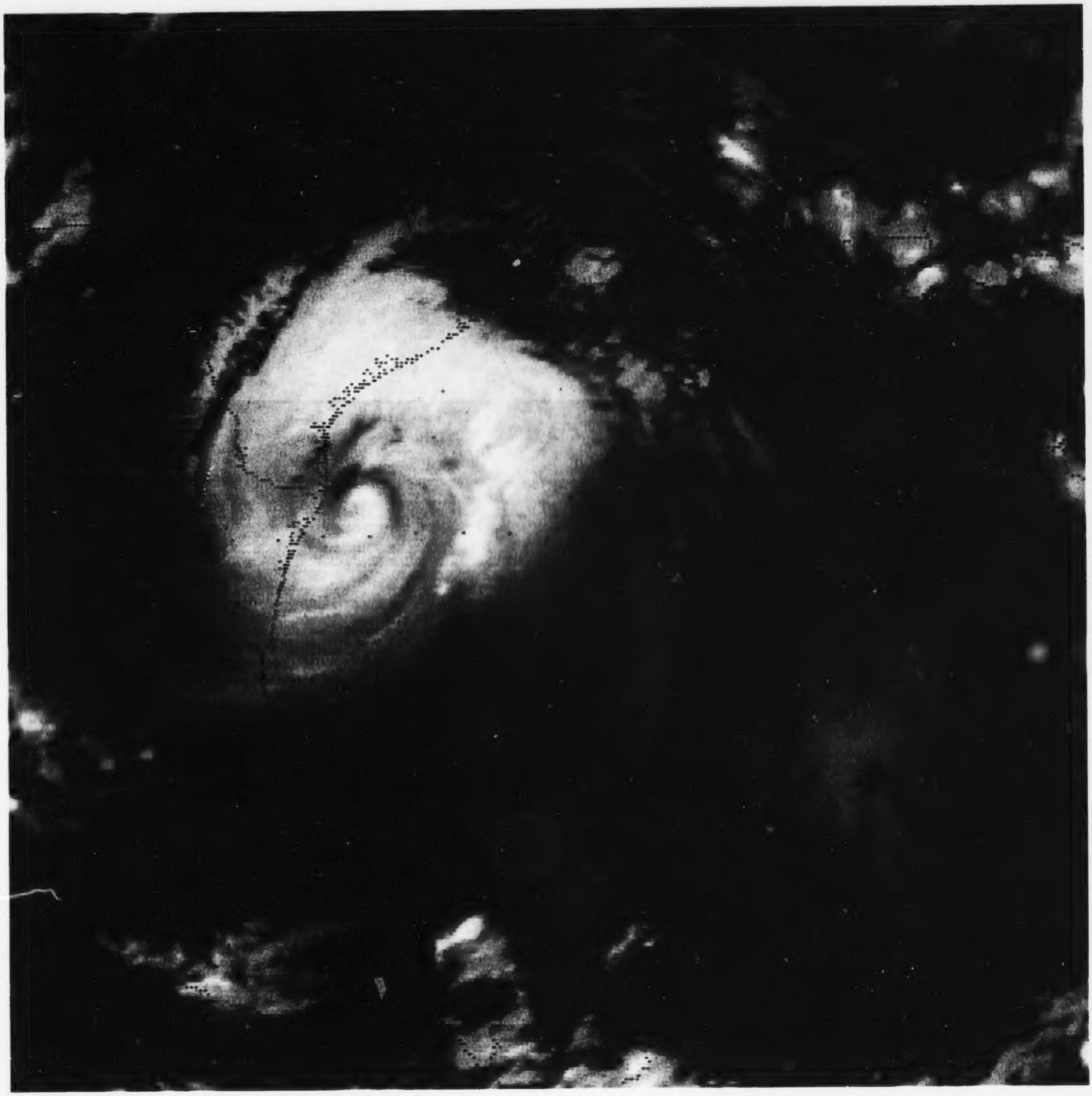
Meteorology is the study of the atmosphere and its phenomena that relate to weather and weather forecasting. A meteorologist is a person who studies the atmosphere and does weather forecasting.

Description of Work

Meteorologists perform professional and scientific work primarily concerned with the phenomena and conditions in Earth's atmosphere, and their effects on human, social, and economic activities. Phenomena having potential adverse effects, which meteorologists seek to predict include hurricanes, tornadoes, blizzards, and droughts. The work requires professional knowledge of meteorological methods, techniques, and theory, and the ability to apply this knowledge in the solution of practical and theoretical problems.

Work performed by meteorologists includes weather analysis, forecasting, air and water pollution advisories, climatology, radar and satellite surveillance and analysis, computer-prepared prognostic guidance, and meteorological research.

Synoptic meteorologists analyze weather data from satellites and worldwide networks of stations equipped with upper-air sounding equipment, radar, and surface-observing instrumentation. *Weather forecasters* prepare a variety of forecasts for the general public and for specialized interests such as aviation, marine, and agriculture. *Research meteorologists* do research in atmospheric physics, refining and advancing meteorological theory, and creating and improving mathematical models of atmospheric processes and events. They work in laboratories and in the field studying severe storm mechanics, weather modification, and new weather prediction techniques. *Climatologists* collect, organize, archive, interpret, and publish climatological data.



The NOAA GOES-5 weather satellite obtained this view of Hurricane Alan, just off the southern tip of Texas in August 1980. (NOAA photograph)

A major employer of meteorologists is the National Oceanic and Atmospheric Administration (NOAA). Its meteorologists are assigned to the National Weather Service Environmental Research Laboratories and the National Environmental Satellite Data Information Service.

After several years of experience and training, a meteorologist generally moves into a more specialized field. Some of these are the following:

Agricultural Meteorology
Mathematical Analysis and Programming
Aviation Forecasting
Marine Forecasting
Central Analysis and Prediction
Radar Meteorology
Climatology
Satellite Meteorology
Fire Weather Forecasting
Spaceflight Meteorology
Hurricane Forecasting
Severe Local Storm Forecasting

Increasingly broad and specialized experience accompanied by graduate study equips a meteorologist for staff or supervisory positions or for research in a specialized area of meteorology.

Location of Work

Meteorologists work throughout the country. The NOAA offices, within the National Weather Service, is a major employer of meteorologists. Meteorologists are located in most of the major cities in the 50 states and in Washington, D.C. They are assigned to National Weather Service Forecast Offices. There is also a large concentration of meteorologists in NOAA's National Meteorological Center located in Camp Springs, Maryland. NOAA's Environmental Research Program has field offices throughout the United States. Research meteorologists are located in Suitland, Silver Spring, and Camp Springs, Maryland; Boulder, Colorado; Kansas City, Missouri; Cincinnati, Ohio; Norman, Oklahoma; Las Vegas, Nevada; Miami, Florida; Idaho Falls, Idaho; Oak Ridge, Tennessee; Raleigh, North Carolina; and Princeton, New Jersey.

Educational and Qualification Requirements

The main fields of study required at the high school and college levels include physics and mathematics (through calculus and differential equations) and meteorology. A minimum requirement for a career in meteorology is a full course of study leading to a bachelor's degree in an accredited college or university, which has included or been supplemented by 20 semester hours in meteorology. This includes 6 semester hours in weather analysis and forecasting, and 6 semester hours in dynamic meteorology.

Career Development Assignments

The National Weather Service conducts a training program to develop its forecaster work force. This program combines on-the-job training (OJT) and course work to provide basic training in facility operations and forecast techniques. The intern will perform, as training and experience proceed, all aspects of the office functions. The OJT will advance from routine to difficult assignments. The career ladder for meteorologists provides for yearly progression, based on satisfactory service and completion of training assignments. At the end of the assignment, the meteorologist may be assigned to another geographical location within the National Weather Service.

A variety of assignments in a meteorologist's career not only helps select an area of specialization, but provides a good background for the specialization itself. Because career opportunities are located throughout NOAA, mobility is an important factor in career development. It is equally desirable that a meteorologist gain experience in international assignments, in view of the global nature of atmospheric phenomena.

Astronomy

by Dr. George R. Carruthers

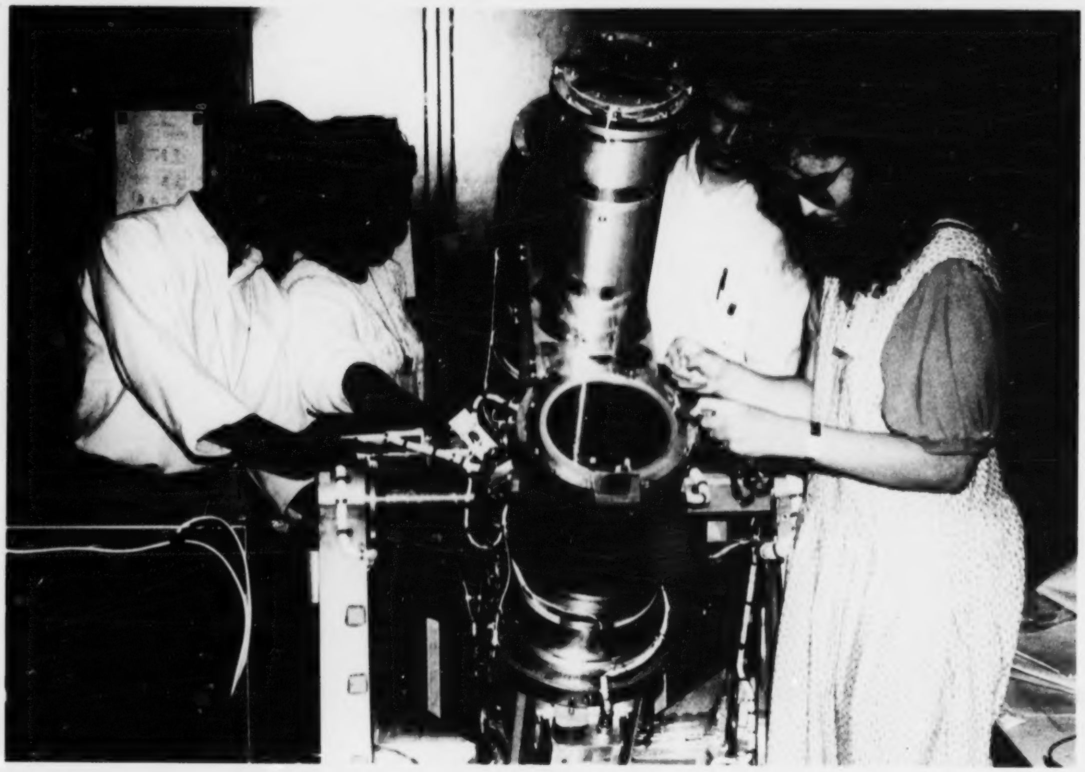
Astronomy deals with the entire universe outside of Earth. As such, it lies at the opposite extreme from particle physics, which deals with the smallest entities of nature. However, astronomy is based to a very high degree on physics. It differs from other sciences in that it is not possible to do actual laboratory experimentation in astronomy; in most cases, we cannot actually visit the object under study, but can only observe it from a distance.

Hence, astronomy is a field dependent on *remote sensing* — study based on observations of light and other forms of electromagnetic radiation received from the object. Thus, the fields of optics and electromagnetism are of fundamental importance to astronomy, since these form the basis by which information is obtained. However, nearly all other fields of physics are involved in interpreting and understanding the information received. Many areas of astronomy also involve chemistry; for example, studies of the composition of planetary atmospheres and of interstellar gas and dust. Even biology is important in determining whether there may be life elsewhere in the universe.

Modern astronomy has been marked by an increasing diversity of wavelength ranges in the electromagnetic spectrum accessible to study, and in types of equipment and theoretical techniques used. Astronomy has become much closer to physics now than it was 100 years ago. As recently as 1960, most astronomy was done with optical telescopes in ground-based observatories, although the then-new field of radio astronomy was gaining prominence. With the advent of the space program and the availability of satellites and other space vehicles, astronomy began to encompass observations in the ground-inaccessible ultraviolet, X-ray, and gamma-ray wavelength ranges. Advances in infrared detector technology resulted in the development of infrared astronomy, first with ground-based telescopes, and then with telescopes carried on high-altitude aircraft, balloons, and space vehicles. Many professional astronomers obtained their academic degrees in physics (or even chemistry) and may have never actually looked through a telescope.

Examples of fields of research in astronomy include studies of planetary atmospheres, stellar atmospheres, stellar structure and evolution, galactic structure and evolution, properties and composition of interstellar material, and

Four students participating in the National Optical Astronomy Observatories/Kitt Peak National Observatory AIHB summer program are shown using a 36-inch telescope at Kitt Peak (NOAO/Kitt Peak photograph)



Summer student Donovan Kirkland, science teacher Rachel Clark, mechanical engineer Steven McAllister, and summer student Jennifer Evans are doing pre-flight preparations of the Naval Research Laboratory's Far Ultraviolet Cameras experiment, which flew on Space Shuttle mission STS-39 in April 1991.

cosmology (the structure, history, and future evolution of the universe). An example of a research topic is determination of how stars and planets are formed. This includes studies of other planets and objects in our solar system to obtain new insights into the history of our solar system, and also studies of regions elsewhere in our galaxy where astronomers suspect that new stars are being formed. Space observatories are becoming increasingly important tools of astronomy. One of the major milestones of modern astronomy was the launching of the Hubble Space Telescope into Earth orbit by the Space Shuttle. This telescope has the potential to be 50 times as sensitive as the largest ground-based telescope, in addition to having 10 times better resolution, and is able to observe ultraviolet wavelengths not observable from the ground. The Compton Gamma Ray Observatory is producing similarly large advances in our capacity to study gamma rays, the most energetic form of electromagnetic radiation. Similar observatories for the X-ray and infrared wavelength ranges are planned.

Educational Requirements and Types of Work

Astronomy is very closely related to physics, hence the educational requirements for astronomy are nearly the same as for physics through the sophomore year of college. Most colleges offer introductory astronomy courses, having minimal science and mathematics prerequisites, which are recommended for those having a general interest in astronomy but who are undecided about choosing it as a major. However, such courses are not essential for astronomy majors, since schools offering astronomy as a major field also have intermediate-level courses in astrophysics. These cover the same subject areas as the descriptive astronomy courses, but with college physics and calculus as prerequisites. In the junior and senior years and in graduate school, astronomy majors take more advanced physics and mathematics courses, as well as more specialized astronomy courses. These latter include celestial mechanics, stellar atmospheres, galactic structure and dynamics, general relativity and cosmology, and other specialties.

As is true in physics, research in astronomy usually requires a Ph.D. degree. Although many astronomers use large telescopes at major observatories, this is by no means the only major research activity in astronomy. Theoretical astrophysicists (including cosmologists) use computers as their major tools. Many astronomers use instruments flown on aircraft, balloons, rockets, and spacecraft — or even underground neutrino detectors. Astronomers who observe X-rays, gamma rays, and energetic particle radiations often have more in common with high-energy physicists than with conventional visible-light astronomers.

People having training in astronomy with B.S. or M.S. degrees may find employment in applied areas such as space flight mission planning; as assistants to research astrophysicists at observatories, universities, and government laboratories; in teaching astronomy at the high school, junior college, and university level; and in planetariums and museums.

Neptune, currently the outermost planet in the solar system, and its largest satellite, Triton, were imaged close-up by NASA's Voyager 2 spacecraft in August 1989. Four times Earth's diameter but 30 times Earth's distance from the sun, Neptune is invisible to the naked eye. It was not even discovered until 1846 and appears little larger than the resolution limit of even the largest ground-based telescopes. Space missions such as **Voyager** *involve large numbers of scientists, engineers, and mathematicians. (NASA photographs)*

Health Physics

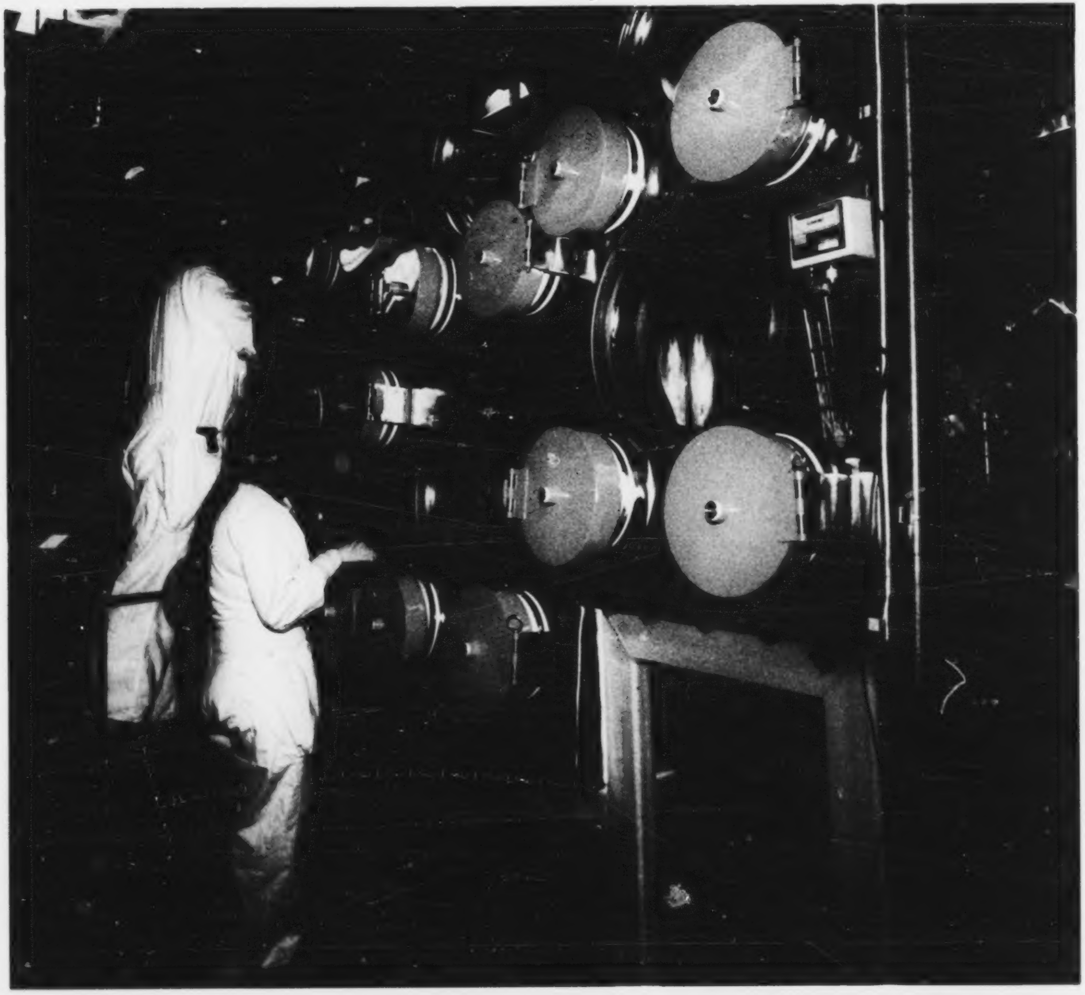
by Hattie V. Carwell

Health physics is another example of an interdisciplinary field. Health physics is concerned with the effects of high-energy radiation (an area of physics) on human health (biology).

Energetic subatomic particles (electrons, protons, neutrons, and atomic nuclei) and electromagnetic radiations (X-rays and gamma rays) can produce harmful effects in humans and other living organisms. Health physics is the profession devoted to the protection of humans and the environment from unwarranted radiation exposure. A health physicist is a person engaged in the study of the problems and practice of providing radiation protection. Understanding the mechanisms of radiation damage, developing and implementing methods and procedures necessary to evaluate radiation hazards, and providing protection to humans and the environment from unwarranted radiation exposure are also concerns of the health physicist.

Types of Work

Implementation of health physics concerns falls into four areas: research, operation, education, and enforcement of governmental regulations. Some health physicists specialize in only one of these fields; however, most find themselves engaged in all four.



Scientists and technicians who work with radioactive and/or toxic materials use glove-boxes, such as that shown here, to avoid contact with the materials and to prevent the accidental release of hazardous materials into the outside environment. (Rockwell International photograph)

In operations, health physicists limit personnel exposure to radiation by controlling the time, distance, and shielding design at radiation facilities and in the radiation work environment. They monitor for the presence of radiation and prevent the spread of contamination. These control measures are used at accelerators, reactors, hospitals, and in the outside environment to evaluate radiation released in the air, soil, and water. They are responsible for maintaining radiation exposure to the lowest practicable limits. To ensure control measures are effective, areas are periodically monitored with radiation survey equipment, and the exposure detected by personnel dosimeters is determined.

Health physicists constantly research new and better ways to understand the behavior of radiation and its interaction with the environment and the human body. They are interested in ways it can be used beneficially, such as to diagnose and treat diseases like cancer. Also, many countries are interested in how radiation can be used in food preservation, in powering small equipment such as pacemakers, as well as in many other industrial applications. Improvements in radiation detection methods and equipment make the control measures more effective and improve the ability of health physicists to evaluate hazards.

Education programs for radiation workers are provided by the health physicist to promote the safe handling of radioactive materials and to reduce the spread of contamination where radioisotopes are in use.

Health physicists enforce the radiation protection guidelines established by various state and federal agencies. These guidelines provide limits for permissible exposure to radiation workers and the general public, both in routine situations and in the case of an accident. Health physicists are employed by federal agencies (such as the Nuclear Regulatory Commission and the Environmental Protection Agency), state agencies, health departments and environmental control agencies, universities and research laboratories, hospitals and medical centers, and various industrial facilities including nuclear power plants. Some health physicists have consulting firms that provide expertise for medical and/or industrial installations that do not employ full-time health physicists.

Educational Requirements

To qualify for a career in health physics, you must have a basic education in physical science plus training in specific areas. High school students who want to prepare for technical or university courses in health physics should follow an academic program that emphasizes mathematics, chemistry, physics, and biology.

Technical training in health physics is available at technical schools, vocational training centers, and sometimes from employers. Approximately 80 technical training institutions and several universities offer programs in health physics or related fields. One- and two-year programs (some leading to an associate degree) include such courses as radioactivity and radioactive decay, radioactive contamination control, environmental radioactivity, nuclear technology, and radiation health.

Experienced and competent technicians are eligible to qualify for certification as Health Physics Technicians. The certification is awarded by the National Registry of Radiation Protection Technologists.

To qualify for professional status, a health physicist must earn at least a B.S. degree in science, with specialized courses in physics, mathematics, chemistry, nuclear engineering, biophysics, medical physics, and radiation biology. More than 50 universities offer either B.S., M.S., or Ph.D. degrees in health physics and related fields such as radiation biology or radiological physics. Graduate degrees are usually required for research and teaching positions. Undergraduate and graduate programs focus on curricula that include interaction of radiation with matter, nuclear physics and engineering, physiology and genetics, radiochemistry, and radiobiology.

Financial assistance is sometimes available through federal and state grants and scholarships, as well as teaching and research assistantships. Professional health physicists are also eligible to receive certification for competence and experience in the field. The American Board of Health Physics prepares and administers the written certification examination.

Computer Science

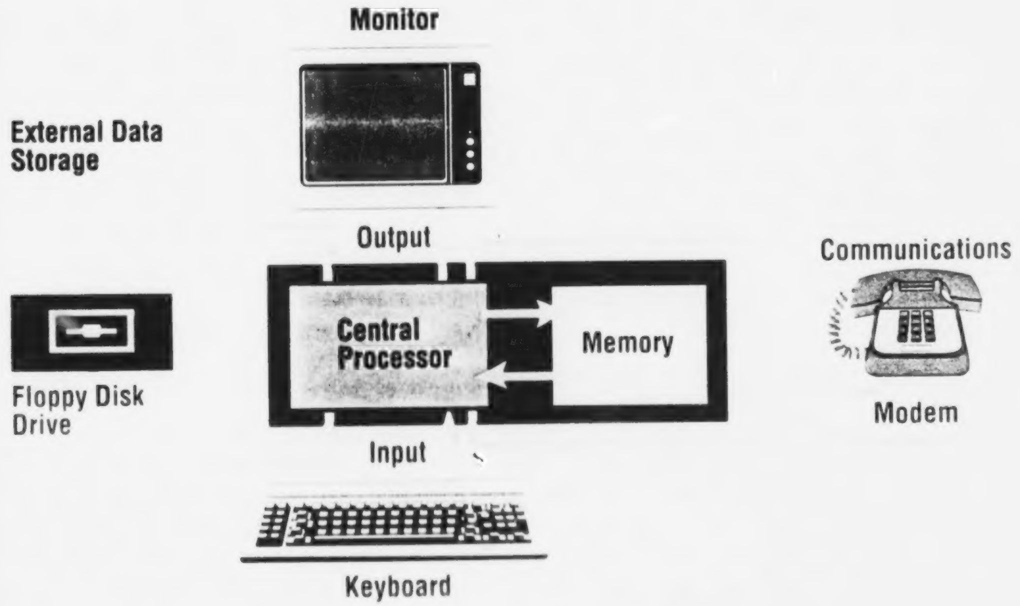
by Rosilyn Seay

Computer science is another example of an interdisciplinary field, having its origins in mathematics and electrical engineering. Computer science is one of the most exciting, challenging, and adaptable disciplines in existence today. It is also one of the newest. The boundaries of the field are so pliable that they overlap almost any other technical field. In fact, nearly all technical fields depend on, or benefit from, the use of computers.

Although the fields of computer science and data processing are new as technical disciplines, the concepts used in computing are not. As soon as commerce developed in early societies, people recognized the need to calculate and to keep track of information. They soon devised simple computing devices and bookkeeping systems to enable them to add, subtract, and record simple transactions. The abacus, which appeared both in ancient Egypt and in China, could be used to add, subtract, multiply, and divide. The first mechanical adding machine was developed in 1642 by the French philosopher and scientist Blaise Pascal. Some 50 years later, the German mathematician Gottfried Leibnitz produced the first mechanical calculating machine that could multiply and divide as well as add and subtract numbers. Finally, the difference engine, which was used to automatically compute and print out mathematical tables that were accurate to five significant digits, was devised by Charles Babbage in the early 1800s. Modern electronic computers were first developed during the 1940s. The earliest models were essentially one-of-a-kind machines that, although experimental in nature, were used for practical applications.

Developments in solid-state electronics, including first the transistor and then integrated circuits, made possible the explosive development of smaller and more powerful computers beginning in the 1960s. The microcomputer or personal computer (PC), weighing only a few pounds, has far more computing power and capability than the early vacuum-tube computers, which filled entire rooms, used thousands of watts of power, and cost millions of dollars to build and maintain.

As recently as the late 1970s, the average person rarely had direct contact with a computer system. Typically, payroll was computer processed, and grades were processed and printed on computer forms. Some retail stores had computerized billing systems. The situation has changed dramatically. More than half of the United States labor force is now in information occupations — jobs that "create, manipulate, or use" information, or work with technologies that do

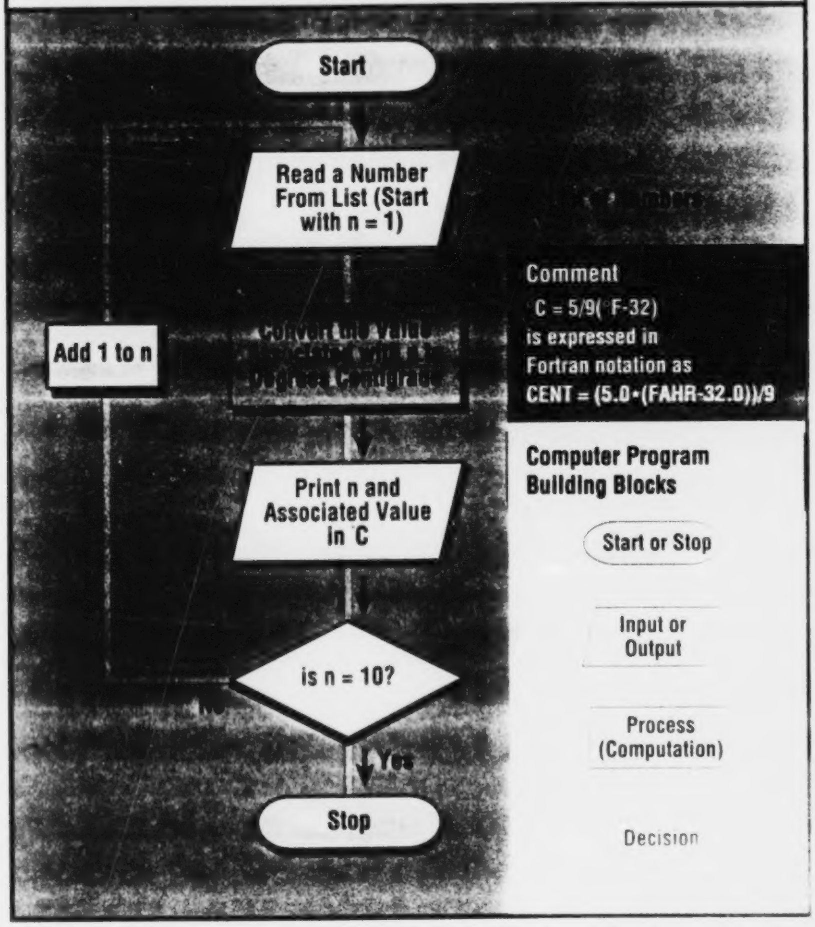


Block diagram of a typical computer system, showing the major components and their interfaces. Components outside of the central processor and memory are often called peripherals; other devices besides those shown here can be used.

A computer program is best visualized and developed by means of a flow diagram. As shown here, the building blocks of the diagram include start or stop instructions, input or output instructions, process (computation) instructions, and decision (branch point) instructions. These can be combined in various ways to achieve the desired result.

Sample Computer Program

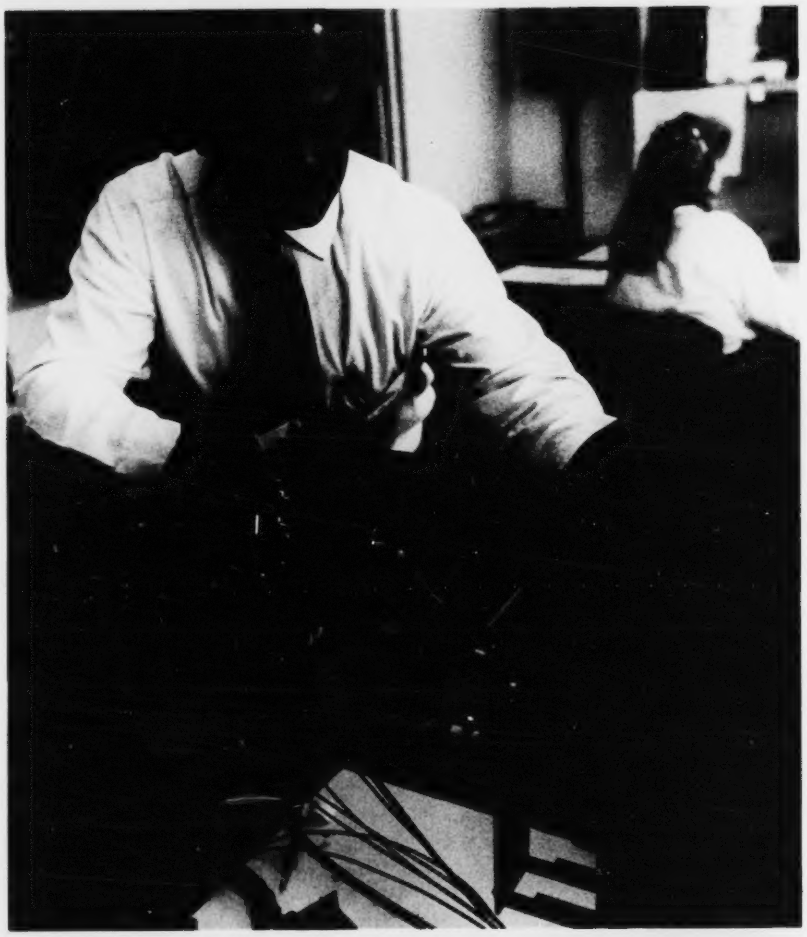
Convert an input list of 10 numbers, labeled n = 1,2,...10, with values expressed in degrees Fahrenheit, into a corresponding list of 10 values expressed in degrees Centigrade.



these things. As pointed out by John Naisbitt in his book, *Megatrends*, the United States has changed from an industrial-based society to one based on information. Computers and data processing have greatly changed how industries, governments, educational institutions, and everyday people perform their work and even how they play. Computers instantly perform the most complicated mathematical calculations, make comparisons, bring together different information, and even choose between lists of alternatives. Everyday examples include computerized airline reservation bookings, automatic 24-hour banking machines, word processors, and video games. More advanced applications include computer-aided design and drafting, computer-controlled machine tools, automatic pilots, and guidance systems for airplanes and space vehicles. The fast-developing field of robotics is an example of one of the newer, most computer-intensive engineering specialties.

Future applications of the computer are bounded only by the limitations of human imagination and creativity. This is what makes the computer field exciting. The many current and potential uses of the computer create varied choices for those interested in taking advantage of, and making the

Software engineer Walter Robinson is shown testing a Spectrometer Interface Module (SIM) for the Imaging Spectrometric Observatory Computer (ISOC) at the NASA Marshall Space Flight Center.



most of. these machines. The many applications of the computer make the career choices, and types of people appropriate to these, very numerous. In general, however, academic specialties that are most directly applicable (in addition to Computer Science, where offered) include Electrical and Electronic Engineering (for the design of new computer systems and integration of these with other systems) and Mathematics and Information Systems (for the application of computers to computation and other tasks).

Types of Work

As mentioned previously, Computer Science covers a wide range of occupational specialties. However, three major categories cover a large portion of these career options: (1) design and maintenance of computer systems (hardware); (2) design and development of computer programs (software); and (3) application of computers to other technical fields (interfacing and integration). The following are more detailed descriptions of some specific occupations.

Computer Design—The design of new computers is driven by current and anticipated applications requiring one or more of the following: greater computational capability (faster speed, larger memory, higher accuracy); lesser size, weight, and power consumption; higher reliability and resistance to adverse environments; and adaptability to a wider range of applications. Computer designers typically have at least B.S. degrees in electrical or electronic engineering, with emphasis on solid-state devices and their computer applications. A knowledge of the mathematical basis of computing, and of computer programming, is also desirable.

Mathematician Valerie L. Thomas of NASA's Goddard Space Flight Center studies global warming trends depicted by the images generated from data collected in the Greenhouse Effect Detection Experiment (GEDEX).

Applications Programming — The applications programmer writes computer programs for specific tasks in business, government, science, or engineering. This person supplies the "thoughts" to computers that enable them to perform these tasks. That is, the programmer plans and organizes the procedures a computer will follow to carry out a task. For jobs in organizations using computers for scientific or engineering work, programmers typically are college graduates with degrees in mathematics, computer science, physics, or a field of engineering. For jobs in business or government that deal with less technical applications, degrees in business administration or accounting may be appropriate, but course work should include computer programming, mathematics, data processing, and statistics.

Computer Operations — The computer operator is the person directly responsible for running the console or main terminal of the computer. These duties include starting up the computer, submitting computer cards or magnetic tapes prepared by the programmer to the computer, and the operation and management of the computer peripherals (hardware connected to the computer) such as printers, tape and disk drives, plotters, and video terminals. Generally, the computer operator does not need a detailed knowledge of the internal workings of the computer, or of computer programming, and a college degree is not usually required. A high school diploma, plus training in the operation and maintenance of the computer, is usually sufficient.

Communications Specialists — Communications involves linking several computers together, accessing a computer from a distance (requiring special hardware, such as telephone modems), and using the computer to manipulate nonlocal hardware such as satellites, for example. There are several possibilities within communications. To produce plans for a communications network, *systems design engineers* draw on an in-depth knowledge of equipment protocols, communications facilities, corporate desires, applications, and business management. The *communications programmer* is a specialist in communications software. This individual provides programs, or software, both for new products and for aiding in the integration of vendor packages to provide the intelligence within the data network. The *communications technician* troubleshoots a hardware problem, performs a diagnostic analysis, and then either repairs the trouble or oversees the repair by the vendor. Most communications specialists come from other fields such as systems programming or operations.

Database Specialist — A database, by definition, is a set of computer records (files) that are logically structured and logically linked to each other. A database management system (DBMS) enables a company or organization to organize, catalogue, locate, store, retrieve, and maintain the information in a database.

There are three major job classifications in the database area. The *database administrator* is responsible for designing, developing, and administering the use of the data within the database. The *database systems programmer* oversees the database package from the systems programming point of view. This includes performing a feasibility study before the package is purchased, installing the package on the computer and making any additional changes necessary such as defining the parameters of the system, and finally debugging it. The *database programmer analyst* must know all the computer instructions (commands) in a standard DBMS package, must understand database concepts, and must know how to structure the programs so that they can be linked together. In many companies, these functions are often performed by one individual. Database personnel generally require a four-year college degree. However, since courses offered at colleges in this specialty are limited, a general background in computers and programming is most appropriate.

Systems Programmers — A systems programmer is responsible for maintaining the operation system of the computer; this is the basic, internal set of programs that enables the computer to accept, process, store, and output data. These programs must be operational before the computer can accept and use applications programs. Generally, a systems programmer must understand the hardware of the computer and the interactions with applications programs. Today, at least a four-year degree and preferably several years of experience in programming of the particular computer system are required. The preferred degrees are in computer science, mathematics, or engineering.

Electrical and Electronic Engineering

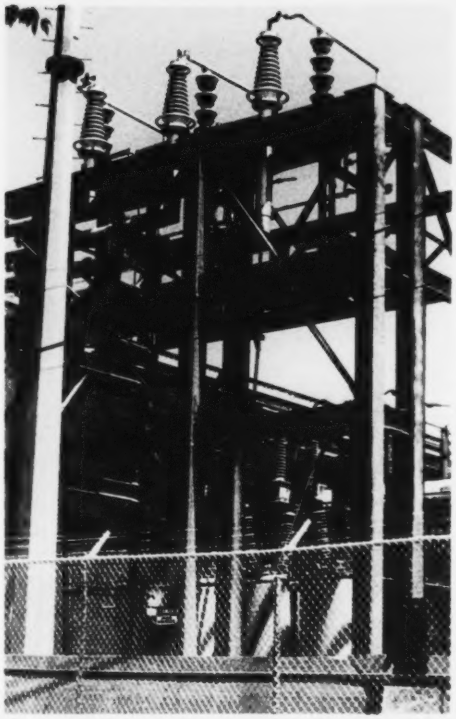
by Dr Samuel G. White Jr

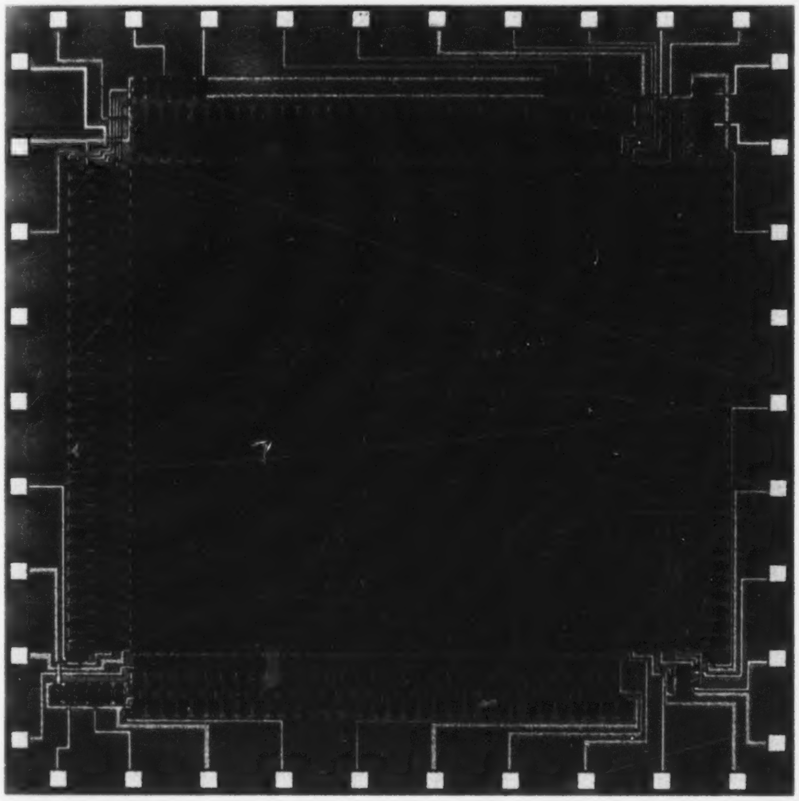
Electrical engineering and electronic engineering are the applications outgrowth of the branch of physics concerned with electricity and magnetism. Initially, (beginning in the latter part of the 19th century), electrical engineering was concerned with the design and development of such devices as electric motors and generators, electrical transmission systems, and electric lighting. Some of the early practitioners of the field include Thomas Edison, Nikola Tesla, Granville Woods, Charles Steinmetz, and Lewis Latimer.

The later development of electronics, which at first used vacuum tubes and, more recently, solid-state devices, originated in the early part of the 20th century and was largely driven by the radio communications demands of World War I. The primary focus was on increasing the transmission frequency (decreasing the wavelength) in order to reduce the size of the antennas and the power requirements of radio communication. The associated research resulted in the development of the vacuum tube, the first major electronic device. Initially, electrical engineers were classified as radio engineers, telephone engineers, or power engineers.

During the era of World War II, further reductions in transmitting and receiving radio wavelengths led to the development of radar and also to peacetime applications in radio and television systems. These and other related developments led to major expansion of the field of electrical engineering, resulting in its being split into two major subfields, electrical and electronic engineering. Electronic engineering includes the areas of telecommunications, recording devices, computers, solid-state devices, control systems, automation, and instrumentation. Electrical engineering includes electrical power generation and transmission, electric motors and other electromechanical devices, and electric lighting.

As vacuum tubes ushered in electronic engineering, the introduction and proliferation of solid-state devices (such as transistors, integrated circuits, and solid-state rectifiers) resulted in major expansions of both electrical and electronic engineering. Electrical and electronic engineering now include a vast variety of applications, including communications equipment (radio, television, recording systems, etc.), computers, control devices and automation, radar, and energy sources such as solar power and nuclear-electric





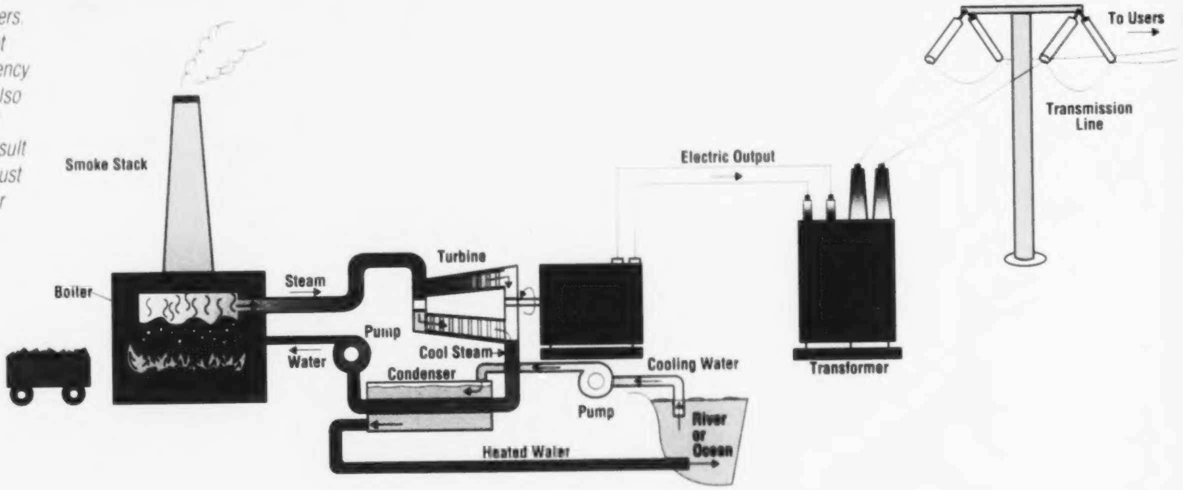
Electrical engineers work with devices and equipment having a wide range of sizes and power levels. At top is a typical electric power substation, which handles many millions of watts of power. At bottom is a highly magnified view of a typical silicon-based integrated circuit, which measures only 4 x 4 millimeters in size and whose power level is measured in milliwatts (thousandths of a watt). This chip is an Analog Programmable Vector-Matrix Multiplier Array, designed and built at the Naval Research Laboratory. (Courtesy of F. Kub, NRL) power systems. In fact, electricity used in one way or another is involved in nearly all of our daily activities and is truly a servant of humanity. It is very difficult to imagine what our lives would be like without it.

The electrical/electronic engineer applies basic physical and engineering principles, both electrical and mechanical, in the design and construction of electric power generation and transmission systems, communications systems, automatic control systems, computers, and other electrical equipment. The basic requirements of electrical and electronic systems change and new designs must provide for the necessary capabilities. For example, a computing machine must be built that will solve problems of greater and greater complexity and at the same time have a means of introducing the problem into the machine as simply as possible. Electrical and electronic engineers are involved in almost all aspects of modern technology and scientific research, including medicine and health, aerospace, ground transportation, and housing. Hence, there are excellent career opportunities in nearly all technically oriented businesses and government agencies. Virtually all modern home conveniences, such as audiovisual entertainment systems, microwave ovens, personal computers, and many automotive systems and accessories are largely the work of electrical and electronic engineers. Most major surveys predict a very high demand for such skills in the future; therefore, the outlook for electrical and electronic engineers is very bright.

Types of Work

Electrical and electronic engineering is the largest field of engineering at present. Areas of specialization include solid-state electronics, computer design, telecommunications, electric power and transmission systems, control systems, industrial electronics, and instrumentation. The following are more detailed descriptions of some of these specialties.

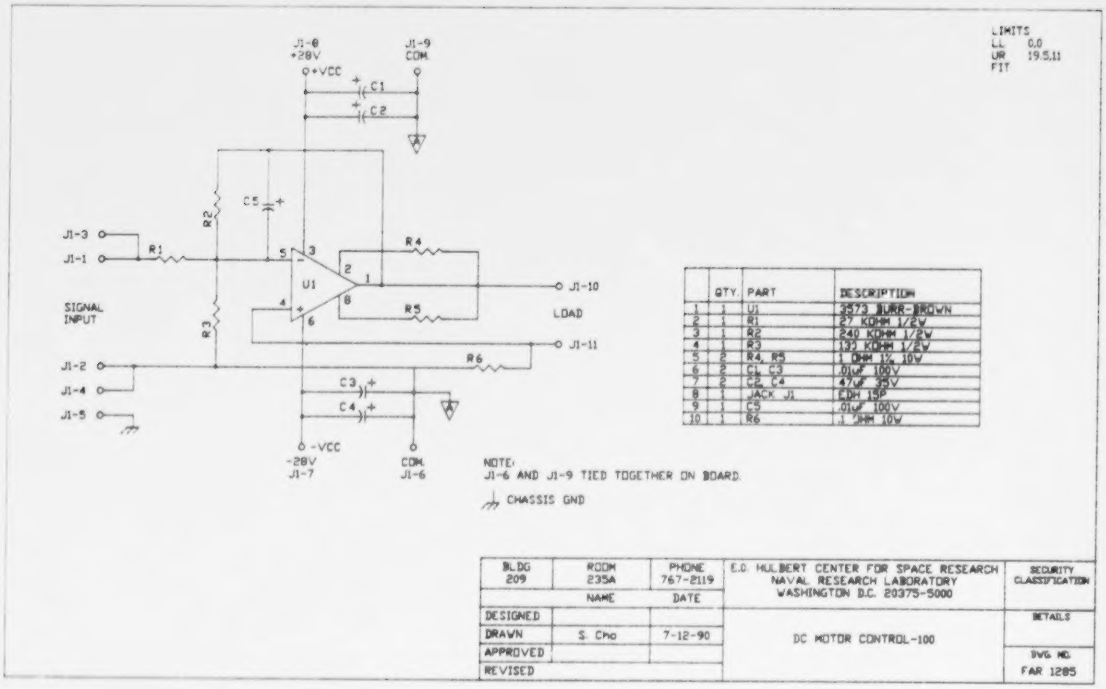
Solid-State Electronics is concerned with devices based on semiconductors such as silicon, which are of central importance to electronic circuits and systems. Examples include solid-state rectifiers (for converting alternating current to direct current), the transistor (used for electrical signal amplification), integrated electronic circuits (containing many transistors and other electronic components on a single semiconductor chip), light-emitting diodes (LEDs), computer memory devices, and electronic imaging devices (such as the charge-coupled device, CCD). As exemplified by LEDs, CCDs, and optical disk recording media, many electronic devices increasingly involve optical as well as electrical signals to meet present and future requirements.



A diagram of a typical electric power generating station. In addition to the use of a coal-fired boiler, as shown, other heat sources (such as a nuclear reactor) can be used, or the generator can be powered by a water-driven turbine or a windmill. The design of such a facility involves many types of technical professionals, including mechanical, electrical, and civil engineers. Considerations include not only maximizing the efficiency of power generation, but also minimizing environmental impacts (such as might result from the smokestack exhaust or from heating of the river water).

An area of energy technology currently being developed makes use of "free" wind energy to generate electricity. The experimental windmill generator shown here was developed by NASA Lewis Research Center, the Department of Energy (DOE) and the Environmental Protection Agency (EPA). (NASA photograph)

A typical electronic circuit diagram. The operational amplifier, U1, is used to amplify an input control signal to power levels suitable for driving an electric motor.



NOTE:
J1-6 AND J1-9 TIED TOGETHER ON BOARD.

	QTY.	PART	DESCRIPTION
1	1	U1	3573 BURR-BROWN
2	1	R1	27 KOHM 1/2W
3	1	R2	240 KOHM 1/2W
4	1	R3	133 KOHM 1/2W
5	2	R4, R5	1 OHM 1% 10W
6	2	C1, C3	.01uF 100V
7	2	C2, C4	47uF 35V
8	1	JACK J1	EDH 15P
9	1	C5	.01uF 100V
10	1	R6	.1 OHM 10W

BLDG 209	ROOM 235A	PHONE 767-2119	E.O. HULBERT CENTER FOR SPACE RESEARCH NAVAL RESEARCH LABORATORY WASHINGTON D.C. 20375-5000	SECURITY CLASSIFICATION
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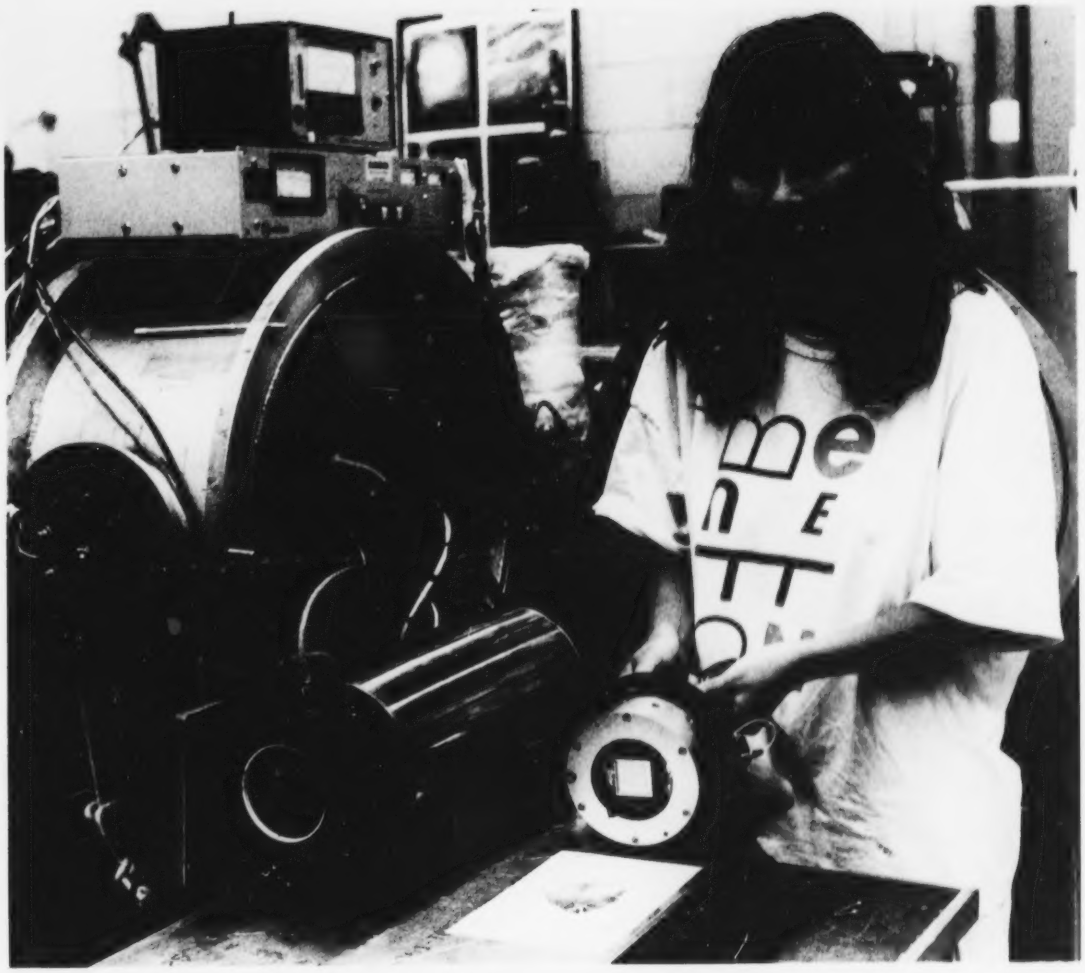
Brian Johnson, electronics engineer at the NASA Marshall Space Flight Center, is testing a control board for the ground-based field million detection system used for shuttle lightning studies.

Computer Design — Design and development of computers presently, and for the foreseeable future, will emphasize providing a capability for processing more data in less time, while requiring less training and skill on the part of the operator (i.e., having user-friendly interfaces).

Telecommunications — The theory and technology of telecommunications include data transmission by electromagnetic wave propagation (radio waves, lasers) and conducted and guided signals (telephones, microwave waveguides, fiber optics). Applications are in commercial and other fixed station services, as well as marine, aeronautical, space, and other mobile communications. Engineers specializing in this field work toward system optimizations, including ways to transmit and receive more information in less time, over greater distances, and (especially in mobile systems) with less power, size, and weight of equipment.

Power Systems — This field involves the requirements, planning, analysis, reliability, operation, and economics of electrical generating, transmission, and distribution systems. These provide electric power for industrial, commercial, public, and domestic consumption.



Charge-coupled device (CCD) arrays are solid-state electronic imaging devices which, in recent years, have largely replaced vacuum-tube television cameras and are used in space flight missions such as Galileo and Hubble Space Telescope. Electrical engineering co-op student Luong-Quyen Phan is shown testing an ultraviolet camera that uses a CCD array (postage-stamp size object on the camera sensor head at right). (NRL photograph)

Instrumentation — Electrical and electronic techniques are used to make measurements of many physical quantities, often not initially electrical in nature (such as temperature, pressure, velocity, or altitude).

Educational Requirements

Students desiring to enter the electrical and electronic engineering professions should begin their preparation in mathematics and science at least by the end of the eighth grade. The study of electrical and electronic engineering requires that the student take high school courses in mathematics and science (including algebra, trigonometry, physics, and chemistry) and other college-preparatory subjects. It is very important that the student learn to enjoy, as well as be able to apply, the principles of mathematics and science.

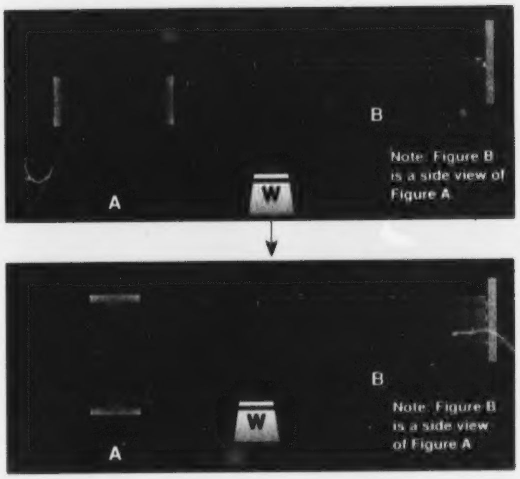
Upon completion of high school, the student enrolls in an engineering college and a curriculum that requires at least four years to complete. During these four years, the student will complete at least one year of course work in mathematics (including calculus and differential equations) and at least one year of basic science (including college physics and chemistry). Other minimum requirements include one year of course work in engineering science (mechanics, circuit analysis, thermodynamics, etc.), one-half year of engineering design, and one-half year of course work in humanities and social sciences. In the second half of the four-year course of study, the electrical and electronic engineering student may choose to specialize in one or more of the following areas, depending on the career field of interest: computer design, robotics, power systems, electromagnetic field theory, communications systems, circuit theory, solid-state electronics, automatic control systems, optical electronics, and others.

Mechanical Engineering

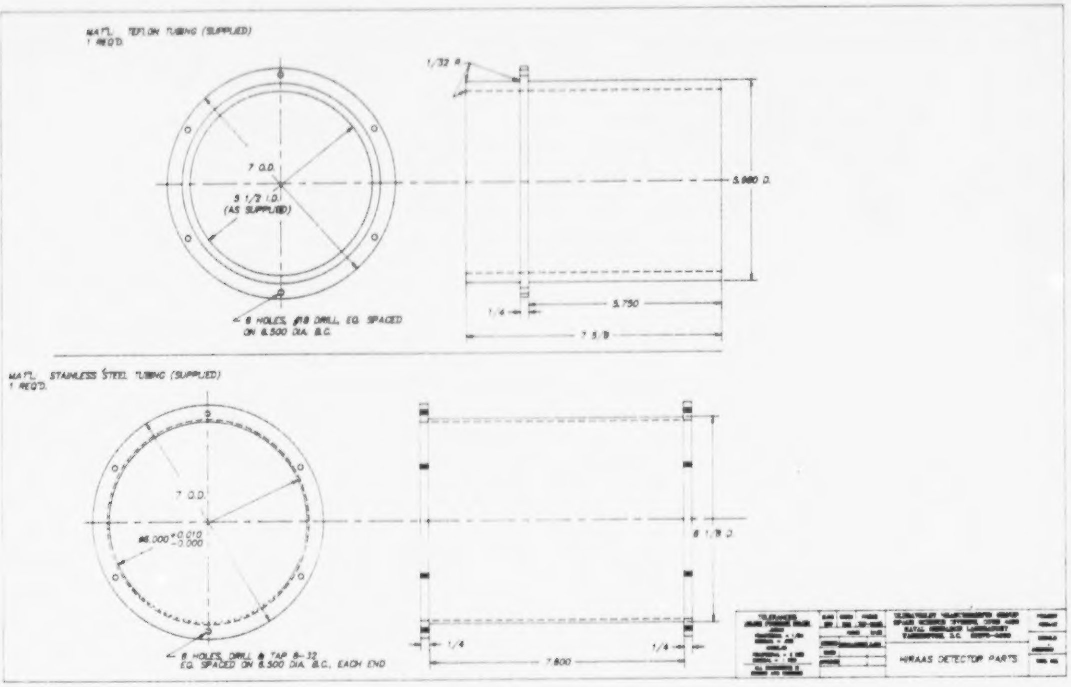
by Rickey J. Shyne

Mechanical engineering is the broadest of all the engineering disciplines and is second only to electrical and electronic engineering in number of people employed. It is an outgrowth of the branch of physics known as mechanics, which deals with the properties and motions of solid bodies and of fluids. Mechanical engineers are involved in the design and development of machinery, which may either generate power or use it by conversion into a more useful form. Examples include internal combustion engines, steam and gas turbines, jet and rocket engines; heating, air conditioning, and refrigeration systems; automobiles, airplanes, trains, and subway systems; manufacturing equipment, computer-aided design and manufacturing, robotics, and others.

Other fields that are outgrowths of mechanical engineering include aerospace engineering, nuclear engineering, materials engineering, metallurgical engineering, and structures engineering. There is also much commonality between mechanical engineering and civil engineering.


B
Note: Figure B is a side view of Figure A
A
W
B
Note: Figure B is a side view of Figure A
A
W

Mechanical and civil engineers use the principles of mechanics (a branch of physics) to design structures in the most efficient manner, that is, to achieve the greatest strength with the minimum amount of material. A typical example is shown here, illustrating how the strength of a given structural element can vary depending on how it is used.

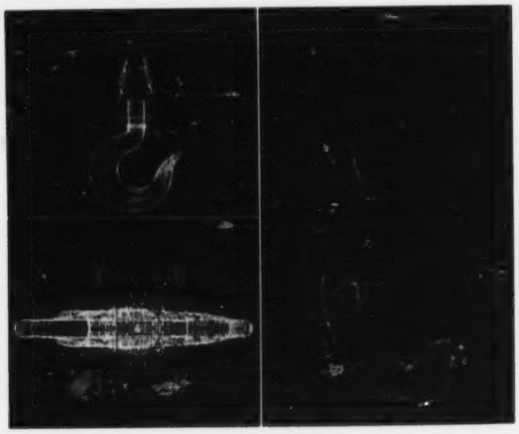

MAT'L. TEFLON TUBING (SUPPLIED)
1 REQ'D.
1/32 R
7 O.D.
5 1/2 I.D.
(AS SUPPLIED)
5.880 D.
6 HOLES, #18 DRILL, EQ. SPACED ON 6.500 DIA. B.C.
1/4
5.750
7 5/8
MAT'L. STAINLESS STEEL TUBING (SUPPLIED)
1 REQ'D.
7 O.D.
⌀6.000 +0.010 −0.000
6 1/8 D.
6 HOLES, DRILL & TAP 8-32 EQ. SPACED ON 6.500 DIA. B.C., EACH END
1/4
7.600
1/4
HIRAAS DETECTOR PARTS

A typical mechanical engineering drawing. An engineer would give this to a machinist to have the parts made.

Types of Work

To provide a proper perspective of what the mechanical engineering discipline includes, a few of its specialty areas are highlighted below.

Automotive Engineer — A mechanical engineer who is involved in the design of vehicles and engines for automotive needs of the future. Automotive engineers design every part of the automobile from something as small as a door latch to something as large as the engine or the front and rear bumper systems.



Monitor display of a three-dimensional engineering drawing developed with AutoCAD™ computer-aided design and drafting software. (Courtesy of Autodesk, Inc.)

Biomedical Engineer — This specialty of mechanical engineering deals with the application of mechanics and/or fluid flow to the medical field. This may include designing a mechanical pump for temporary replacement of the human pump — the heart — or designing replacement parts (prostheses) for failed or fragile human limbs.

Fluids Engineer — A mechanical engineer who specializes in the design and/or manufacturing of fluid flow systems or processes. For example, this person would design a water piping system for a new building per specifications from a general contractor.

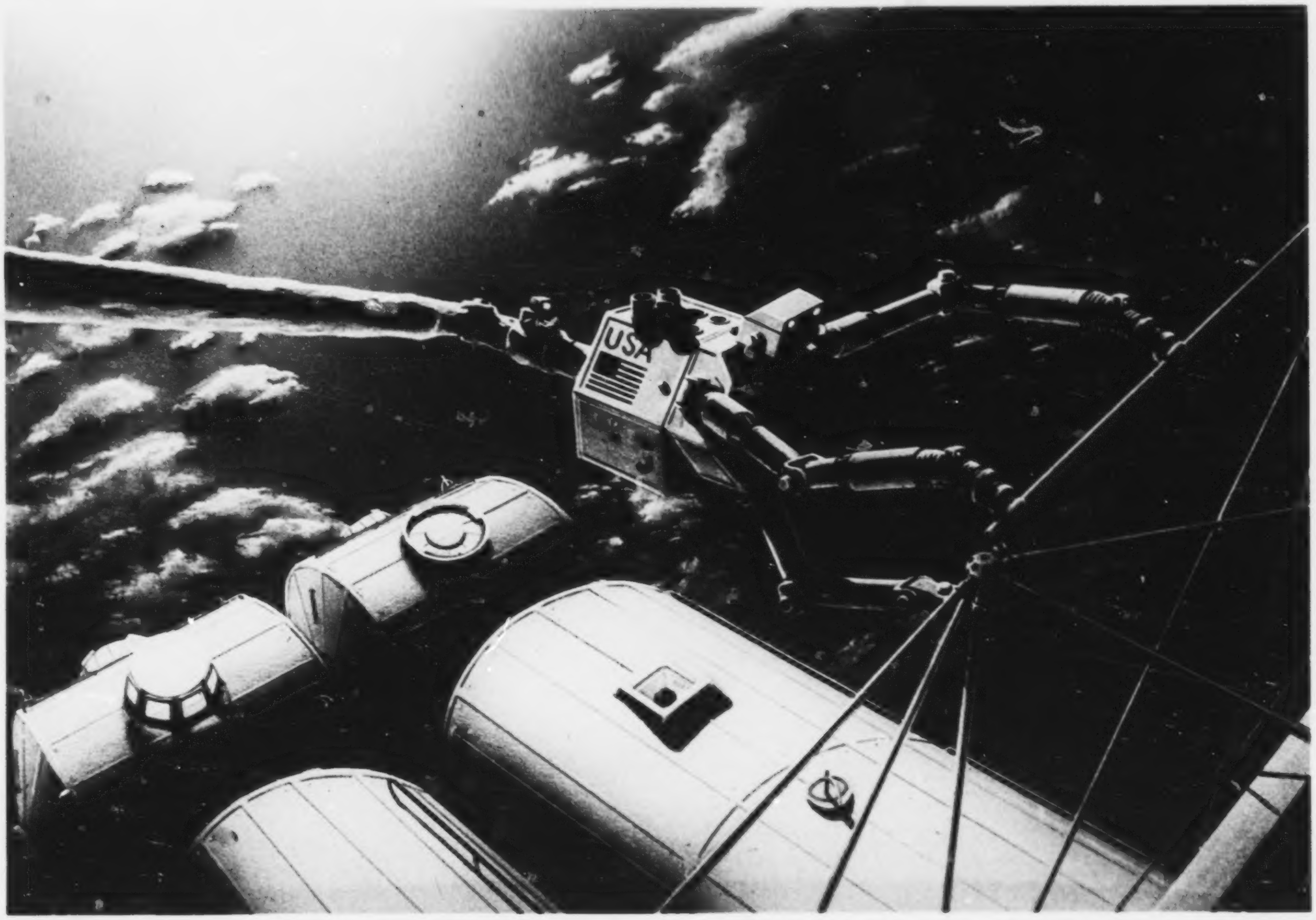
Computer technology has resulted in significant changes in the ways in which engineers and architects go about their design work. Previously, the hallmark of the mechanical or civil engineer was the drafting board, on which new designs were drawn by hand (top). Now, computer-aided design and drafting has largely displaced hand drawing in most areas of engineering (bottom). (Photographs taken at offices of Jackson and Tull, Chartered Engineers)

NASA mechanical engineer, Amanda O. Harris, Chief of Payloads Quality Assurance Office, assesses Transfer Orbit Stage flight hardware to ensure compliance with drawing requirements.

Heating, Ventilation, and Air Conditioning (HVAC) Engineers — HVAC engineers deal with the design of heating, ventilating, air conditioning, and refrigeration systems for various applications. HVAC engineers may be involved in designing a refrigeration system for a frozen food section at your local grocery store, or domestic solar energy systems for homes in the 21st century.

Manufacturing Engineer — This mechanical engineering specialty is involved with the manufacturing industry and its products. Manufacturing engineers design and update machines and/or processes used to manufacture every product conceivable, such as airplanes, automobiles, books, cookies, paper towels, etc. Increasingly, robotics is an important area in manufacturing engineering. Robots consist of computer and electrical as well as mechanical systems; hence, robotics involves mechanical, electrical, computer, and systems engineers.

The Flight Telerobotic Servicer (FTS) assembles sections of the permanently manned Space Station truss structure in this artist's concept. The multi-armed FTS will be used to assist astronauts in the assembly of the Space Station while in orbit and will help maintain scientific instruments on the station.



Electrical engineers, mechanical engineers, and civil engineers work together to develop modern rapid transit systems.

Systems Engineer — This specialty of mechanical engineering is concerned with the design and analysis of mechanical or thermal systems. These systems are usually experimentally or mathematically modeled by the systems engineer to determine their particular performance characteristics.

Mechanical engineers are employed across the spectrum of government agencies and private industry. Because of the great breadth of the field, mechanical engineers find employment in a great variety of technical endeavors. Government employment of mechanical engineers ranges from research and development positions to careers in intelligence, depending on the agency. The employment opportunities within private industry are unlimited, and a mechanical engineering graduate can expect enormous flexibility in selecting a place of employment.

Educational Requirements

Pursuing a major in mechanical engineering will require a student to have a solid mathematical and scientific foundation. Interested high school students should pursue a college-preparatory curriculum, which includes algebra, geometry, trigonometry, pre-calculus, calculus (if offered), biology, chemistry, physics, and computer programming, in addition to English, history, and composition. Participation in school-sponsored science fairs and exhibits also will provide the student with valuable experience in the engineering thought process.

Once in college, mechanical engineering majors will be required to take fundamental courses in mathematics, including calculus, differential equations, and linear algebra, as well as in the sciences, including chemistry and physics. Additional courses in engineering graphics, computer science, English, history, and humanities courses will be taken in the first two years. The majority of the mechanical engineering courses taken in the junior and senior years in college can be specialized to fit a student's personal interests and/or strengths. Students can specialize further by pursuing a graduate program in their area of career interest and expertise.

Civil Engineering

by James M. Sawyer

The Key Bridge in Washington, D.C., is a typical example of the design work of civil and structural engineers. (Courtesy of Jackson and Tull, Chartered Engineers)

Civil engineering involves the design and construction of large stationary structures. In western history, it is an outgrowth of military engineering. However, its principles were applied in ancient times to build the cities and temples of antiquity. Civil engineering is the oldest branch of the profession as it is known today.

Modern civil engineering is concerned with public works such as highways, bridges, tunnels, harbors, dams, and airfields. Civil engineers assist in the design and development of central-city areas, including sewage systems, and transportation system facilities such as roads, subway tunnels, and airport runways and terminal facilities. They work with architects in the design of buildings and with mechanical engineers in the design of transportation systems.

Types of Work

To gain more insight into civil engineering, the different specialties of this field will be examined. A dam project will be used as an example in defining these specialized areas. This hopefully will accomplish two objectives. The first is to help clarify the definition of the specialty by giving an example of how it is used on a project. The second objective is to show how the different specialties interact. It is rare, in modern times, for a project not to require several different engineering specialty areas.

Civil engineers and structural engineers are involved in many public works projects such as this one, which is the reconstruction of the Minnesota Avenue bridge in Washington, D.C. (Courtesy of Jackson and Tull, Chartered Engineers)

Hydraulics Engineer — This is a civil engineer who specializes in the study of waterflow and the drainage properties of water systems, natural and artificial. It is the calculations made by this person that determine that a dam is required to control the flooding on a river. The hydraulics engineer would also determine where on the river the dam would be located and how high it should be.

Structural Engineer — This civil engineer specializes in examining, by use of mathematics, the forces acting on any large stationary structure, in this case the dam. After the forces have been determined, the structural engineer then defines the type and size of the materials used to resist the forces. The whole process is called structural design. This process differs from architectural design in that style and appearance are not prime concerns.

Soils Engineer — There are hundreds of different types of soil and rock. Each has its particular property under pressure. The soils engineer examines the soil and rock at the site of the dam and calculates how much weight this material can take. This person also will design or assist in the design of the foundation of the dam. Soils engineers specialize in the study of soil and rock properties as they relate to supporting the weight of large stationary structures.

Construction Engineer — When all the designs are complete and the drawings are made, this engineer's job starts. The construction engineer estimates the cost of the project and then plans, schedules, and manages the actual construction of the dam. This civil engineering specialty is concerned with the business aspect of the project as well as the technical aspects. Contract negotiations and construction sequence, as well as material quality and specifications, are all parts of this person's job.

All of the civil engineering specialties discussed above are required to bring a dam project from inception to completion. The same engineers with the possible exception of the hydraulics engineer would be required on any large civil engineering project. Listed below are the other major specialty areas of civil engineering.

Traffic Engineering — This involves the design of streets and traffic control patterns in major urban areas.

Highway Engineering — This specialty deals with the location and design of major highways.

Sanitary Engineering — The environmental movement of the 1960s and 1970s helped to create this area of specialization. This engineer designs and manages waste water management and cleaning systems.

Municipal Engineering — In order to manage the design and construction of the numerous civil engineering projects that often are required in urban areas, cities and towns employ their own civil engineers. These engineers deal with a wide range of projects from water supply to street maintenance.

Again, it should be stressed that all of the specialty areas discussed are a part of the civil engineering discipline. In undergraduate study in civil engineering, most of the different specialty areas are covered. The area that one eventually specializes in as a career will depend on personal preference, advanced studies, and/or employment opportunities.

There are three main employers of civil engineers: government agencies, engineering consulting firms, and construction companies. The construction engineers are usually employed by construction companies as estimators, schedulers, surveyors, and construction managers. Consultants usually offer specialized services to their customers. Therefore, one may find any or all of the specialty areas mentioned on the staff of a consultant.

Government agencies often provide a specialized service to society and therefore will require the employment of different types of engineers. For example, working for the Corps of Engineers will eventually lead a new graduate to a specialization in one of the areas discussed in the dam example. Working for any of the State Departments of Transportation could lead to a career as a structural, traffic, highway, or construction engineer. Employment with a city or town may lead to a specialization in municipal or sanitary engineering. These are just a few of the potential employers of civil engineers. There are numerous private sector employers in addition to consulting and construction companies.

Educational Requirements

To become a civil engineer, you must start preparations early in high school. As in all technical careers, mathematics and science are the foundations of civil engineering. A student planning to major in this field in college should take all of the mathematics offered in high school, including algebra, geometry, and trigonometry. Also, the basic sciences, biology, chemistry, and physics, should be taken.

As was mentioned earlier, it is possible to become part of a specialized area of civil engineering by advanced studies. Most universities offer graduate-level courses in most of the specialty areas. For example, it is possible to receive a Master of Science degree in civil engineering with a concentration in soil mechanics. This advanced study approach is recommended if you intend to pursue a career as a consulting engineer.

Aerospace Engineering

by Dr. George R. Carruthers

The Space Shuttle is truly an aerospace vehicle, in that it combines aspects of space and air vehicle technologies. The Shuttle has reusable liquid-propellant (hydrogen + oxygen) main engines (at the base of the orbiter vehicle) fed by the expendable (orange colored) external tank. Reusable solid-propellant boosters (attached to the sides of the external tank) provide additional thrust during the early stages of flight. The reusable airplane-like Shuttle orbiter must withstand extremely high temperatures when it reenters Earth's atmosphere at the end of an orbital flight mission; its outer surface is made up of thousands of heat resistant (white and black) ceramic tiles.

Aerospace engineering is the modern terminology for the combination of the fields of aeronautical (atmospheric flight) engineering and astronautical (space flight) engineering. In most respects, it has its origins as a branch of mechanical engineering, although celestial mechanics (a branch of astronomy) is an important part of astronautics (therein known as astrodynamics). Aspects of electrical engineering (including computers) are increasingly important parts of aerospace engineering.

The major subfields of aerospace engineering include *aerodynamics, structures, propulsion,* and *astrodynamics.* These may be applied to the design of aircraft and spacecraft, propulsion systems, and space flight mission trajectories. At a more basic level, these rest primarily upon a physical foundation of mechanics (including fluid mechanics) and thermodynamics. Mathematics and computer science are important in all subfields of aerospace engineering.

Some examples of recent achievements in aerospace engineering include the development of the Space Transportation System, or Space Shuttle. Major problems that had to be overcome included development of a lightweight, reusable thermal protection system (thermal tiles) and the high-performance, multiple-reuse hydrogen/oxygen fueled main engines. Other recent technology advances include development of more fuel-efficient passenger aircraft and of a solar-powered aircraft. Future planned developments include a permanently manned space station in Earth orbit, improved space transportation systems to lower the cost per pound of putting payloads in Earth orbit, and further improvements in the fuel efficiency (and reduction of the noise output) of passenger aircraft. Aerospace engineers are also increasingly involved in other related activities such as development of ground and water transportation vehicles, environmental control systems, and the development of new energy sources.

Aerospace engineers have designed new jet aircraft for airline use, such as the Boeing 757 and McDonnell Douglas MD-80 shown here, which are both quieter and more fuel-efficient than earlier models.

Educational Requirements

Aerospace engineering requires a firm foundation in science and mathematics, as do most other physical science and engineering specialties. It is important to have taken mathematics through trigonometry and pre-calculus in high school, as well as chemistry and physics, before entering college. The first year of college, engineering majors start out with calculus and physics. The curriculum for most of the first two years is similar to that of other engineering disciplines, such as mechanical engineering. Major courses taken (mostly in the junior and senior years) include dynamics of incompressible and compressible fluids, structures, propulsion, astrodynamics, and aerospace vehicle design.

Aerospace engineers with B.S. degrees are employed mainly by the aerospace industry; however, some are also employed in government organizations. The range of options available can be enhanced by taking elective courses in such areas as electronics, computer science, and physics. Many positions require graduate study beyond the B.S. degree; in particular, research occupations and college teaching positions require the Ph.D. degree.

Aerospace engineer Sharon Ferguson monitors the integration of elements as the Advanced X-Ray Astrophysics Facility (AXAF) is shown in the Shuttle cargo bay during a maintenance check simulation.

Chemical Engineering

Chemical engineers apply the principles of chemistry, as well as those of engineering and physics, to develop means for mass production of chemical products such as plastics, synthetic fibers, medicines, and detergents. They have developed methods for the manufacture of a wide variety of fuels, plastics, and pharmaceuticals from crude oil and for extracting high-value metals from low-grade ores. They are currently developing means for producing gasoline from coal.

The curriculum of study for chemical engineering is similar to that for chemistry, but includes course work in engineering-related areas such as thermodynamics, fluid dynamics, process design, and control and electronics.

Biology student Steven Walker and astrophysicist Dr. George Carruthers are shown recovering their sounding rocket payload the morning after its launch at White Sands Missile Range. The payload obtained far ultraviolet spectra of stars and carried an experiment to study the effects of acceleration on chlorella algae. (U.S. Army photograph)

Industrial Engineering

Industrial engineers analyze and plan ways to increase the efficiency of workers, materials, and equipment for the most effective production of goods and services in all types of industries. They select processes and methods to be used in manufacturing a product. They develop plant layouts for machinery and decide the sequence of making the parts. Standards for the performance of workers and wage scales are established by industrial engineers. More pleasant working environments and improved productivity result from their work. Often, industrial engineers are found in management because they can evaluate technical situations, make improvements, and communicate with workers.

Metallurgical Engineering

Metallurgical engineers specialize in determining the properties of metals and their alloys, and their applications in useful products. Among their objectives are maximizing the strength, high temperature resistance, and corrosion resistance of metals, and also minimizing their weight and cost in various practical applications. Metallurgical engineers also seek to improve processes for extracting metals from ores, refining them and removing impurities, and converting them into useful forms for the manufacture of goods. They also seek to better understand the structure of metals as a basis for future developments.

First image of the Global Biosphere produced by combining data from two different satellite sensors. One of the most notable features is the clear delineation of the equator through increased plant abundance and the differences between the equatorial Atlantic, Indian, and Pacific Oceans.

Ceramic Engineering

Ceramic engineers are concerned with the properties and applications of a class of inorganic materials known as ceramics. These include glassware, bricks, porcelain, and more exotic materials, in applications ranging from home uses (dishes, decorative items, furnace linings, and construction materials) to high-technology uses such as missile nose cones and nuclear reactors. The ceramic engineer develops methods for processing clay and other nonmetallic materials into a variety of useful forms and also studies the properties of these materials and develops means of improving them for particular applications. For example, an important area of current activity is to improve the fracture resistance of ceramics so that their superior heat resistance can be used to advantage in automotive and aircraft engines.

Nuclear Engineering

Nuclear engineering is one of the most modern fields of engineering; it is an outgrowth of nuclear physics, but also involves many aspects of mechanical engineering and other engineering fields. It is primarily concerned with the design, construction, and operation of nuclear power plants and fuel processing facilities. These range from large electric power generation systems and nuclear submarine power plants to space power systems based on nuclear reactors or on radioisotope heat generation systems. One of the major fields of current activity is the development of means for controlling thermonuclear fusion as a new source of power. By this process, the heavy hydrogen (deuterium) in sea water could serve as a nearly limitless, clean source of energy. Nuclear engineers are also involved in other applications, such as use of radioisotopes in medicine, food preservation, and radiographic inspection of metal parts.

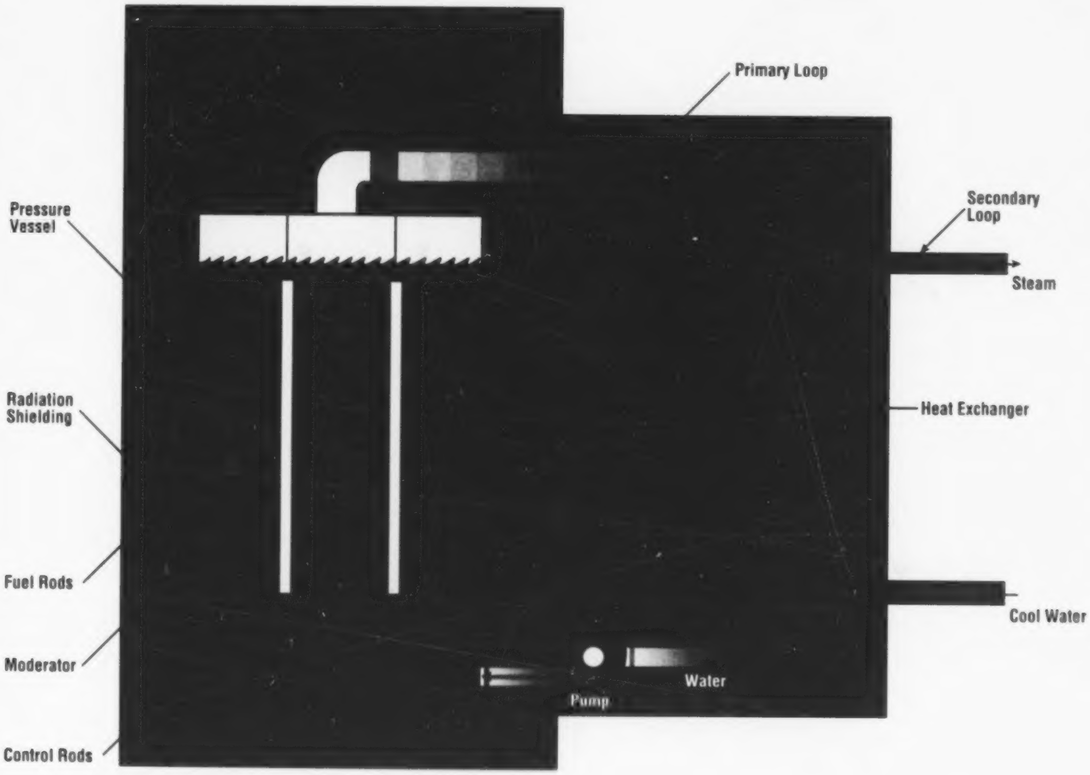


Diagram of a typical nuclear reactor power station. This can be used in place of the coal-fired boiler (shown on page 42) to run an electric power station. An advantage of nuclear power is that one pound of uranium in a nuclear reactor releases as much energy as 1,000 tons of coal or 5,000 barrels of oil. Nuclear engineers are concerned with the control and containment of high-energy nuclear radiation and radioactive materials, as well as with the high temperatures and pressures that are common to other power sources.

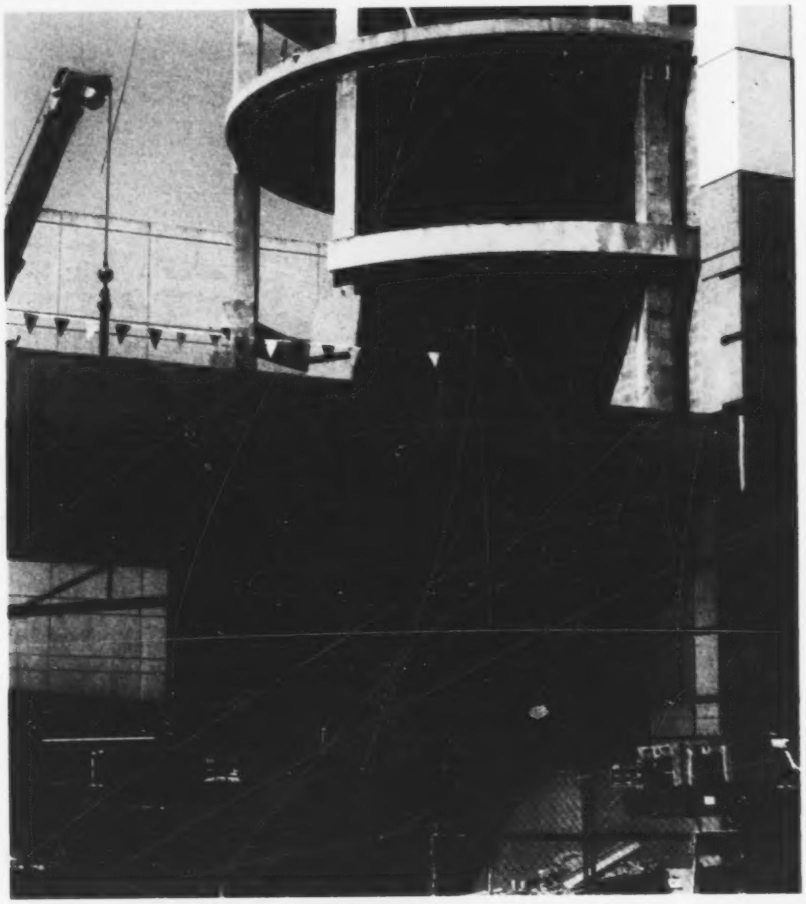
Architecture

by Dallas Lauderdale and Leroy J. H. Brown

Architecture is the art of conceptualizing, planning, and designing structures of open and enclosed spaces to house the various activities of humans and modern civilization. Architects design a wide variety of structures, such as office buildings, churches, hospitals, houses, and airports. They also design multibuilding complexes for urban renewal projects, college campuses, industrial parks, and new towns. Besides designing structures, architects may select building sites, prepare cost and land-use studies, and conduct long-range planning for land development.

Such buildings and other constructs begin with the design, planning, and vision of the architect. Most of them know instinctively what their own particular design style should be, whether it be of the romantic, sophisticated, modern, or ethnic genre. The architect's unique vision creates the esthetics of an original, individual style. Beyond that, environment, type of building or structure, and locale dictate specifics. Man's architectural heritage, over time, can be defined as a pictorial guide to the generations of human endeavor and progress and their expressions of that progress through the medium of architectural design. These designs are as diversified and distinctive as the components of society, molding the old, new, and futuristic; curiously enriching and unique to each individual designer — combining conception, ideas, and vision to form an innovative, exciting, and composite whole.

Designing a building involves far more than planning an attractive shape and exterior. Buildings must also be functional, safe, and economical, and must suit the needs of the people who use them. Architects take all of these things into consideration when they design buildings.



Architects and architectural and civil engineers are concerned with the planning and design of new buildings.

Landscape architects plan the best use of land areas for such projects as parks, airports, golf courses, highways, shopping malls, and housing developments. They use trees and shrubs to create a pleasant environment, and design walkways and lighting. They advise on potential land uses, analyze natural features of a site, and work with other architects to harmonize buildings with their surroundings.

Architects provide a wide variety of professional services to individuals and organizations planning a building project. They are involved in all phases of development, from the initial discussion of general ideas with the client through construction. Their duties require a variety of skills — design, engineering, managerial, and supervisory. On large projects or in large architectural firms, architects often specialize in one phase of the work, such as design or administering construction contracts. This often requires working with others such as engineers, urban planners, interior designers, and landscape architects.

During the past decade, the growth of the human population has reached gigantic proportions and is expected to reach six billion by the year 2000. Such indices suggest that the need for architects will expand accordingly to plan and design housing for this populace.

Architectural designs have changed to meet today's expanding societal needs. Environmental conditions such as air pollution, acid rain, and water pollution have influenced our society and produced a new genre in architectural design. Buildings must be designed to withstand natural hazards such as wind storms and earthquakes. New concepts in building materials and health considerations will greatly influence future building designs. Fortunately, the innovative stance of the schools of architecture and engineering, and of city planners, appear equal to the challenge.

Specific Description

The architect and client first discuss the purposes, requirements, and cost of a project. Based on the discussions, the architect writes a report specifying the requirements the design must meet. The architect then prepares carefully scaled drawings presenting ideas for meeting the client's needs.

After the initial proposals are discussed and accepted, the architect develops final construction documents that incorporate changes required by the client. These documents show the floor plans, elevations, building section, and other construction details. Accompanying these are drawings of the structural system, air-conditioning, heating and ventilating systems, electrical systems, plumbing, and landscape plans. Architects also specify the building materials and, in some cases, the interior furnishings. In developing designs, architects follow building codes, zoning laws, fire regulations and other ordinances, such as those that require easy access by handicapped persons. They also work with structural, civil, and other engineers as required to assure an adequate design.

Throughout the planning stage, the architect may make changes to satisfy the client, who may decide that the design is too expensive or may propose additions to the original plan. The architect may also assist the client in obtaining bids, selecting a contractor, and negotiating the construction contract. As construction proceeds, the architect visits the building site to ensure that the contractor is following the design using the specified materials, and that the quality of work meets the specified standards. The job is not complete until all construction is finished, required tests are made, and construction costs are paid.

Academic Curriculum and Career Opportunities

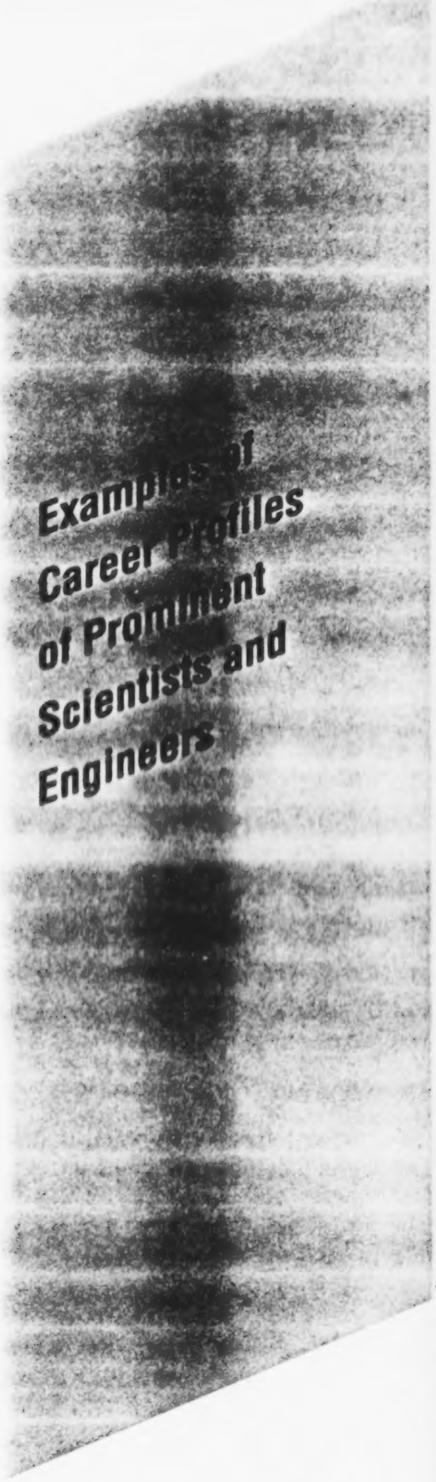
A typical college architecture program includes courses in architectural history and theory, design, graphics, engineering and urban planning, as well as mathematics, physics, economics, computer science, English, and the humanities. In 1985, the National Architectural Accrediting Board had accredited the programs of 92 schools offering professional degrees in architecture. Most of these schools offer either a five-year curriculum leading to a Bachelor of Architecture degree or a six-year curriculum leading to a Master of Architecture degree. Students may also transfer to professional degree programs after completing a two-year junior or community college program in architecture. Many architecture schools also offer graduate education for those who already have a first professional degree. Although such graduate education is not essential for practicing architects, it is desirable for those engaged in specialties or in research and teaching.

All states and the District of Columbia require individuals to be registered (licensed) before they may call themselves architects or contract for providing architectural services. To qualify for the registration examination, a person must generally have at least a Bachelor of Architecture degree from a program accredited by the National Architectural Accrediting Board and three years of acceptable experience in an architect's office. In many states, the experience must be in the Intern Architect Development Program, an apprenticeship program for architects. As a substitute for the professional degree in architecture, a few states still accept other combinations of formal education and experience (usually much more than three years) for admission to the registration examination, but this route to a license is rapidly being eliminated. Many architectural school graduates work in the field even though they are not registered. However, a registered architect is required to take legal responsibility for all work.

Students planning a career in architecture should have some artistic ability, at least to the extent of being able to make reasonable freehand sketches. They should have a capacity for solving technical problems and should be able to work independently. They also must be prepared to work in a competitive environment where leadership and ability to work with others are important. Flexibility and patience are needed when clients reject plans or request changes after final plans are developed. Students who work for architects, engineers, or building contractors during summer vacations can gain useful experience.

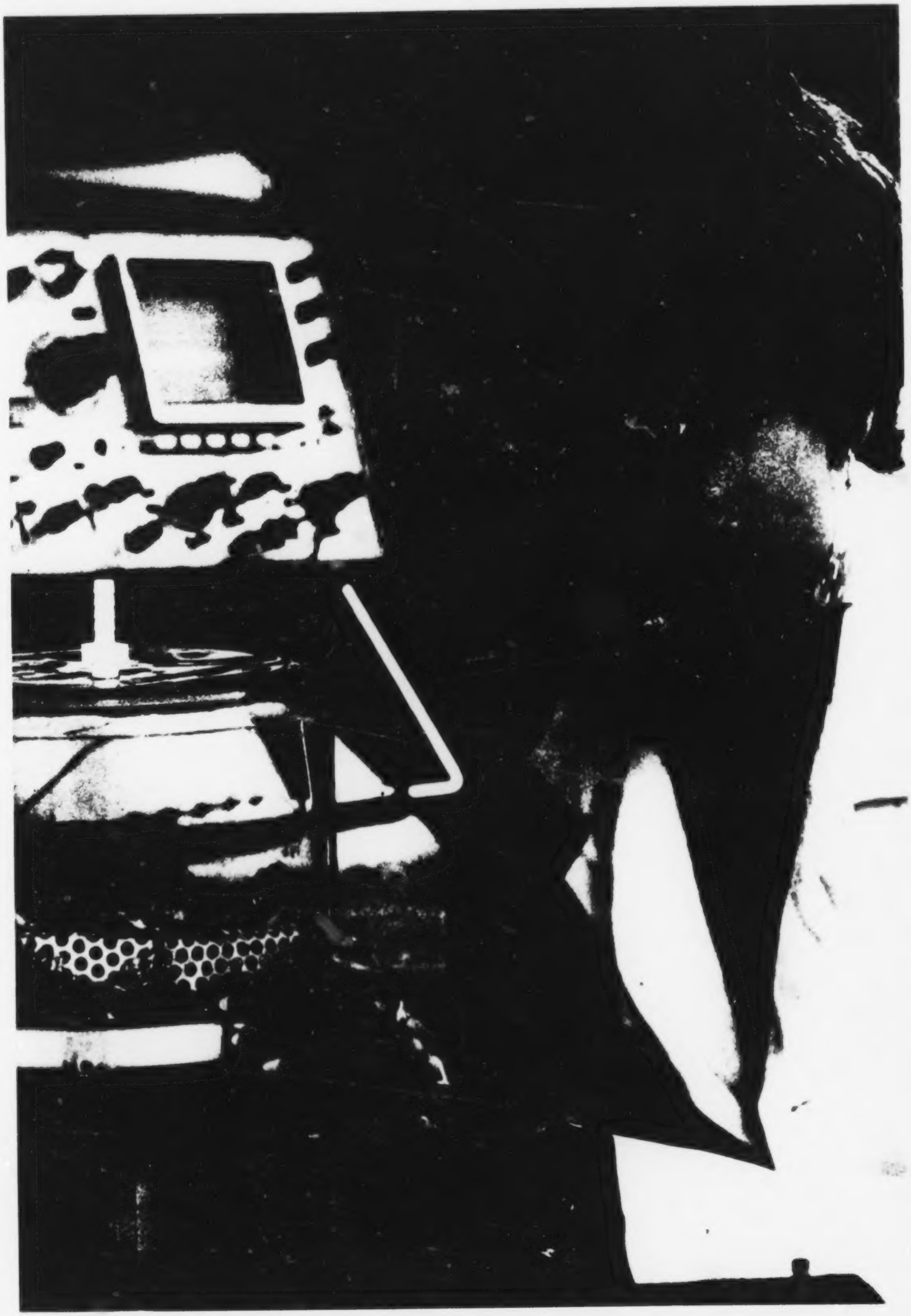
New graduates usually begin in architectural firms where they prepare architectural drawings and make models of structures under the direction of a registered architect. They may also design, administer construction contracts, do research on building codes and materials, or write specifications for building materials, methods of installation, quality of finishes, and other related details. Graduates with degrees in architecture also enter other related fields such as graphic, interior, or industrial design, urban planning, civil engineering, or construction.

In large firms, architects may advance to supervisory or managerial positions. Some architects become partners in established firms. Often, however, the architect's ultimate goal is to own a firm.



Examples of Career Profiles of Prominent Scientists and Engineers

Many of the Department of Energy's national laboratories and facilities, NASA centers and Department of Defense agencies such as the Naval Research Laboratory provide students with summer opportunities that involve scientific research and the experience for future careers.



Chapter III. Examples of Career Profiles of Prominent Scientists and Engineers

This chapter presents examples of professionals in technical occupations who have achieved high standing in their fields. You should view these examples as encouragement to take the proper steps so that you, too, can attain career goals in technical fields and perhaps make similar outstanding contributions to society. In these examples, note that the common feature of all of these outstanding professionals was their willingness to study and work hard, and their persistence in pursuing their goals despite obstacles such as lack of money to pay for education, discrimination, strong competition, and difficulty of the course work or occupation.

The people cited as examples were selected from currently living and active scientists and engineers; however, African Americans, Hispanics, and Native Americans have made significant contributions to technical fields throughout our nation's history. Pioneers of these fields who are no longer living, such as Elijah McCoy, Granville Woods, and George Washington Carver, are discussed in other publications, some of which are listed in the Bibliography.

Dr. Thomas M. Alcoze

Zoologist

For the past three years, Dr. Alcoze has been Director of the Center for Native Education and Cultural Diversity at the Center of Excellence in Education, Northern Arizona University. As director, he is responsible for development of teacher certification programs for Native American and other culturally diverse students. Development of culture based science and mathematics curriculum using environmental science as a focus. He is also adjunct professor for the School of Forestry.

Prior to working at the University of Northern Arizona, Dr. Alcoze was Associate Professor of Native Studies at the University of Sudbury in Ontario, Canada. He was responsible for establishing a Native Studies department and Native School of Social work.

Dr. Alcoze has published many publications over the past 20 years with his most recent being, "Multiculturalism in Mathematics, Science, and Technology: Readings and Activities." Dr. Alcoze is currently working on several research projects, including *Resource Conservation Among Indigenous Nations*, which is an examination of contemporary science and ecology.

Dr. Alcoze received a bachelor's degree in Biology and a master's degree in Environmental Biology from the University of North Texas in 1969 and 1972, respectively. Dr. Alcoze completed a doctorate degree in Zoology from Michigan State University in 1981.

Dr. Javier J. Bautista

Physicist

Dr. Bautista is the Supervisor of the Advanced Cryoelectronics Group and Research Technology Objectives and Plans Manager of Radio Systems Development for the Advanced Systems Program at the Jet Propulsion Laboratory in Pasadena, California. His group is responsible for the improvement of the earth-based receiving elements of the spacecraft-to-earth communications link to meet the future navigation, telemetry and science needs of the Deep Space Network. This includes the development of ultra-low noise cryogenically-cooled microwave amplifiers, masers, and superconducting devices.

Since joining the Jet Propulsion Laboratory in 1981, Dr. Bautista has been directly involved in the evaluation of high critical temperature superconducting materials and development of ultra-low loss microwave filters and slow-wave maser structures.

Prior to working at the Jet Propulsion Laboratory, Dr. Bautista was a Senior Engineer at Texas Instruments. He set up the first production prototype Fourier Transform Infrared Spectrometer (FTIR) for the characterization of electronic grade silicon. He also developed a program to correlate FTIR data with other silicon characterization techniques.

In 1971, Dr. Bautista graduated from St. Mary's University in San Antonio, Texas with a bachelor's degree in physics. In 1974 and 1979, he received a master's degree and doctorate in Physics from Michigan State University, respectively.

Col. Guion S. Bluford, Jr., Ph.D.

Aerospace Engineer and Former NASA Astronaut

Guion S. Bluford, Jr., was the first African American to fly in space, aboard the eighth flight of NASA's Space Shuttle (STS-8) in August 1983. He participated in this five-astronaut flight crew as a Mission Specialist. He is a Colonel in the U.S. Air Force. He was selected as a Mission Specialist Astronaut by NASA in 1978.

Guion S. Bluford, Jr., was born in Philadelphia, Pennsylvania. He earned a B.S. degree in Aerospace Engineering from Pennsylvania State University in 1964. He joined the Air Force and attended pilot training at Williams Air Force Base in Arizona and received his pilot's wings in January 1965. He then went to F-4C combat crew training in Arizona and Florida and was assigned to the 557th Tactical Fighter Squadron in Cam Ranh Bay, Vietnam. He flew 144 combat missions, 65 over North Vietnam.

In July 1967, he was assigned to the 3630th Flying Training Wing at Sheppard Air Force Base in Texas, as a T-38A instructor pilot. He served as a standardization/evaluation officer and as an assistant flight commander. In early 1971, he attended Squadron Officers School and returned as an executive support officer to the Deputy Commander of Operations and as School Secretary for the Wing.

In August 1972, he entered the Air Force Institute of Technology residency school at Wright-Patterson Air Force Base in Ohio. In 1974 he received an M.S. degree with distinction in aerospace engineering, after which he was assigned to the Air Force Flight Dynamics Laboratory at Wright-Patterson as a Staff Development Engineer. He served as Deputy for Advanced Concepts for the Aeromechanics Division and as Branch Chief of the Aerodynamics and Airframe Branch in the Laboratory. He received a Ph.D. degree in Aerospace Engineering, with a minor in Laser Physics, from the Air Force Institute of Technology in 1978, and a master's degree in Business Administration from the University of Houston, Clear Lake in 1987.

In 1978, Bluford was one of a group of 35 astronaut candidates selected by NASA, which included Dr. Ronald E. McNair and Col. Frederick D. Gregory. He, with McNair, was one of the 20 Mission Specialist selectees from this group (the other 15 were Pilot Astronaut selectees). He was subsequently appointed to the flight crew of the STS-8 mission.

The eighth mission of the Space Shuttle, the fourth fully operational flight, was launched on August 30, 1983. It was the first night launch of the Shuttle program. It returned September 6, 1983, landing at Edwards Air Force Base in California, also at night (also the first night landing). During the mission, the crew deployed a communications satellite and conducted numerous other experiments. Bluford, as Mission Specialist, participated in these experiments and in the operation and monitoring of the Shuttle flight systems. He later flew as Mission Specialist on the German Spacelab D-I Shuttle mission (STS-61A), launched in October 1985. He flew as Mission Specialist on STS-39, a Department of Defense (DoD) Shuttle mission launched April 28, 1991, which conducted a wide variety of basic and DoD-applications research experiments. His most recent flight was as a mission specialist on STS-53, a Department of Defense Shuttle flight. This mission was launched December 2, 1992.

Dr. Bluford is the recipient of many awards, including the National Society of Black Engineers Distinguished Scientist Award (1979), and the National Technical Association President's Special Award, which was presented to him at the 1982 NTA Convention in Baltimore. He was selected as Black Engineer of the Year in February 1991.

Dr. Bluford resigned from NASA in June 1993.

Dr. Guion S. Bluford, Jr. (Colonel, USAF), Astronaut and Aerospace Engineer

Dr. Jewel Plummer Cobb

Cell Biologist

Solving some of the mysteries of cancer has been the life's work of Dr. Jewel Plummer Cobb, a cell biologist. Her research has focused on mechanisms controlling the differentiation and growth of malignant pigment cells.

Understanding how cancerous cells develop is one way of obtaining better ideas for ways to treat cancer. Her research has been funded by the National Institute of Cancer and the American Cancer Society.

Combining her research interest, classroom instruction in biology and zoology, and outstanding performance, Dr. Cobb advanced steadily through the academic ranks. After graduating from Talladega College, she received a master's degree and Ph.D. degree from New York University. From instructor of anatomy at the University of Illinois Medical School to assistant professor of research surgery at the Post Graduate Medical School at New York University, and later professor of biology at Sarah Lawrence College, she advanced her career. She moved to Connecticut College as dean of the college and professor of zoology. She held a similar position at Douglass College, Rutgers University, until she became president of California State University in 1981. Her career is a model of success. Despite the demanding position, Dr. Cobb found the time to develop her professional skills while fulfilling her role as a loving and caring mother.

For excellence in the field of education and cell biology, she has been recognized by her peers and appointed to the Boards of the National Institute of Medicine and the American Council on Education. She is a fellow of the New York Academy of Science. Honorary degrees have also been conferred upon her: Wheaton College in Massachusetts conferred the Law Letters Doctorate, Lowell Technology Institute conferred a Doctorate of Science, and 17 other institutions did likewise.

Dr. Frank Crossley

Metallurgist

Dr. Frank Crossley, a distinguished metallurgical engineer, earned the first doctorate ever given by the Illinois Institute of Technology in metallurgy. As a senior research scientist at Lockheed, he developed a metal alloy called transage. Transage is a titanium alloy, much lighter than steel but six times as strong, and is corrosion resistant. Most recently, he was the technical principal investigator for materials and processes at Aerojet Propulsion Division from which he retired in 1991. His responsibilities included assuring the quality of materials and processes in manufactured items. In October 1990 Aerojet awarded him the R.B. Young Award, a $3,000 gift, in the area of quality and manufacturing. He competed against quality managers throughout the various divisions of Aerojet Corporation.

Dr. Crossley is privately involved in making transage, the supermetal he developed almost 20 years ago, a commercial success. It was once thought to be too expensive to use in consumer products other than in the chemical industry and the Lockheed L-1011 jumbo jets flown by TWA, Delta, Japan Air Lines, and other commercial carriers; and in desalination plants converting sea water to potable water. Although it would be possible to make a super-strong, lightweight automobile with it, the cost would be prohibitive to buyers. However, there is now a hope of developing transage into a widely used commercial product by using it to make dental prostheses such as bridges and braces. Commercial production on a large scale would also reduce the cost of other possible applications.

Crossley's undergraduate education was actually obtained through a Navy training program. His college studies were interrupted by World War II. The Navy program was an accelerated one because of the wartime crisis. Crossley completed his B.S. degree in only 2 ½ years. He decided in high school to study chemical engineering, but later switched to metallurgy. He felt that metallurgy could be better used to explain cause and effect. Besides, earlier he had decided against a career in art, and the study of the structure of metals helped him to recapture that interest because under a microscope, metals appear to Crossley much like abstract art.

When Dr. Crossley was at Lockheed, he managed a staff of 60 charged with achieving the least cost for manufactured articles consistent with weight and structural requirements and reliability, establishing specifications for materials and processes, and working with the Navy on the maintenance and repair of equipment and hardware returned from service.

Dr. Meredith Gourdine

Physicist and Energy Systems Engineer

Rediscoverer of an 18th-century energy conversion method, Dr. Meredith Gourdine has developed bold new ideas in the field of electrogasdynamics (EGD). Electrogasdynamics is a process concerned with the interaction of charged particles with a moving gas stream. Through this interaction, very high voltage can be produced from a low voltage originally generated. The phenomenon has been known to scientists since the late 1700s. The trouble was that no one could figure out how to harness the principle to generate enough electricity to make it practical, especially for modern needs.

After graduating from Cornell University, Meredith Gourdine pursued a Ph.D. degree in Engineering Science at California Institute of Technology. Unlike most of his classmates, Gourdine was not content to build a career with a long established firm. He worked for the Aeronautical Division of Curtiss-Wright Corp. until he developed an interest in electrogasdynamics. His employer was not interested in the EGD generator that he developed. So, he decided to take a chance and start his own company, Gourdine Systems, Inc. (now Energy Innovations, Inc.), after raising $200,000. Initially, his laboratory was in his garage with a staff of one. Today, it is a multimillion dollar corporation with an impressive staff of engineers. Gourdine Systems has developed a number of products and processes based on the use of EGD technology. The Gourdine EGD concept has been applied to four major areas: energy conservation, paint spraying systems, air pollution control, and painting. The technique Gourdine developed may be used for refrigeration for preserving foods, supplying cheap power to heat and light homes, burning coal more efficiently, making sea water drinkable by taking the salt out of it, making painting and coating processes easier, and reducing the amount of pollutants in smoke. It has been applied to non-contact printing processes. Methods for controling industrial, residential, automotive, and diesel exhaust into the atmosphere have been developed as well. More than 20 systems and processes have been patented in the United States, throughout Europe, and in Japan and Canada.

One of the advantages of the Gourdine systems is that they can do a more effective job than other conventional systems, at a much lower cost for installation and operation because of their small size and low voltage power supply requirements. Gourdine's bold ideas are changing the world and making work and everyday living easier and healthier. Dr. Gourdine is now blind, but in spite of this, he continues to pioneer the advancement of electrogasdynamics.

Dr. Frank Greene

Electrical Engineer

Dr. Frank Greene is currently a director of Networked Picture Systems, Inc., and has held the position of President from August 1989 until January 1991. Networked Picture Systems sells computer systems for color printing and image retouching. The company's software and hardware emphasize high-quality printed color and creative design.

Dr. Greene founded Technology Development Corporation (TDC) in 1971. TDC specialized in software and services for scientific applications and electronic testing. The name was changed to ZeroOne Systems, Inc., in 1985, when a segment of Technology Development Corporation was spun off and taken public using that name. In 1987, ZeroOne was sold to Sterling Software and Dr. Greene continued as a group president until 1989. Dr. Greene is now a director of the new Technology Development Corporation in Arlington, Texas, as well as a director and president of Networked Picture Systems in Santa Clara, California.

Dr. Greene was a development engineer and project manager with Fairchild Camera and Instrument Co. from 1965 to 1971. His responsibilities included magnetic and semiconductor memory system design and project management for the Illiac IV memory system. From 1961 to 1965 he was an electronics officer in the U.S. Air Force, where he earned the rank of Captain.

Dr. Frank Greene,
Electrical Engineer

Dr. Greene's education and experience in electrical engineering and business has enabled him to corner a unique market in system development. He received his B.S. in electrical engineering from Washington University, his M.S.E.E. from Purdue University, and his Ph.D.E.E. from the University of Santa Clara. He is currently a member of the Board of Trustees of Santa Clara University. He has authored or co-authored ten technical papers and two books and holds a patent on "the uses of faculty circuits in position coding." Dr. Greene entered the computer software business when it was just a budding enterprise.

David Hedgley, Jr.

Mathematician

David Hedgley is a senior mathematician/programmer with the NASA Ames-Dryden Flight Research Facility in Edwards, California. He has spent more than 20 years with NASA working on projects involving systems development and analysis. His mathematical abilities have been demonstrated in conceptional development and application of mathematical methodology capable of resolving complex state-of-the-art problems, analytical techniques to advance the systems disciplines, and criteria to enable projects to end with the desired results. His record of achievements includes the formulation of higher mathematical applications in solving flight research problems, data reduction of aerodynamic data and experimental phenomena, and numerous innovations in software packaging. His most widely recognized achievement is a proven solution to the "hidden-line problem," which is applicable for use on any computer in a real-time environment.

In his position as a NASA mathematician, Mr. Hedgley serves as a specialist in the planning and execution of major projects requiring the development of mathematical approaches, formulation of mathematical models into forms amenable to solution by modern computers, and design of systems requirements for maximum reliability in aerodynamic data reduction. He performs the analysis and develops solutions to flight research problems that are complicated by numerous variables and parameters. He also provides consultation and advisory services to research engineers, data analysts, and management.

The projects he has worked on include development of a mathematical formula that simulates an electronic filter for use on an IBM mainframe computer in support of the lifting bodies project, solution to the radiation heat transfer problem as it relates to structures, solution to the classical hidden-line problem in graphics, solution to the classical silhouette problem, development of the "Real-Time Operations Executive" for a navigation strap-down system of an airborne computer, and solution to the printer-circuit board problem.

Mr. Hedgley received his B.S. in biology and chemistry from Virginia Union and his M.S. in mathematics from California State University. In addition to his work at NASA, he has taught statistics at the Antelope Valley Community College in California.

The accomplishments of Mr. Hedgley have not gone unnoticed. He was a member of the Beta Kappa Chi Honorary Society during college and was honored for his sustained superior performance at NASA. He received the Best (Scientific) Paper of the Year Award in 1976, the national Julian Allen Award in 1984, the National Space Act Award (the highest monetary award ever given to a NASA Ames-Dryden employee) in 1984, the Exceptional Engineering Award in 1983, the Sustained Superior Award in 1983, a Quality Increase for Superior Achievement in 1982, and was selected for inclusion in the Book of Distinguished Americans in 1985.

Dr. Shirley A. Jackson

Theoretical Physicist

Shirley A. Jackson, a theoretical physicist at AT&T Bell Laboratories in Murray Hill, New Jersey, was the first African American woman to earn a Ph.D. from the Massachusetts Institute of Technology (MIT). Dr. Jackson, a native of Washington, D.C., received the B.S. degree in physics from MIT in 1968 and the Ph.D. in theoretical particle physics from MIT in 1973. During her student years at MIT, she did volunteer work at Boston City Hospital and tutoring at the Roxbury (Boston) YMCA. After earning her doctorate, she was a research associate at the Fermi National Accelerator Laboratory in Batavia, Illinois (1973-74 and 1975-76), and a visiting scientist at the European Center for Nuclear Research (1974-75), where she worked on theories of strongly interacting elementary particles. Since 1976, Dr. Jackson has been at AT&T Bell Laboratories, where she has done research on various subjects including charge density waves in layered compounds, polaronic aspects of electrons on the surface of liquid helium films, and most recently, optical and electronic properties of semiconductor strained layer superlattices. In 1986, she was elected a Fellow of the American Physical Society for her research accomplishments. In 1991, she received an honorary Doctorate of Science from Bloomfield College, New Jersey, and was also elected a Fellow of the American Academy of Arts and Sciences.

Dr. Jackson studied in Colorado, Sicily, and France, taught at MIT, and has lectured at several institutes. She has received numerous scholarships, fellowships, grants, and awards. She is a member of the American Physical Society, a past president of the National Society of Black Physicists, and a member of several other professional societies.

Dr. Shirley A. Jackson, Physicist

In 1985, New Jersey Governor Thomas Kean appointed Dr. Jackson to the New Jersey Commission on Science and Technology. She was reappointed for a five-year term in 1989. She has also served on committees of the National Academy of Sciences, American Association for the Advancement of Science, and the National Science Foundation, promoting science and research and women's roles in these fields. Dr. Jackson is a trustee of MIT, Rutgers University, Lincoln University (Pennsylvania), and the Barnes Foundation. She has been a vice president of the MIT Alumni Association and is on three MIT visiting committees: Physics, Electrical Engineering and Computer Science, and the Sloan School of Management.

Jerry T. Jones

Electronics Engineer and Manufacturer

Determination and a dream made the multimillion dollar corporation, Sonicraft, a reality for its president Jerry Jones. He developed a basement operation into one that has its headquarters in Chicago and offices in Boston and in Washington, D.C., and which employs more than 200 people. The makings of that dream were first sparked at the age of four when Jones' father bought him a radio when he was still living in Sledge, Mississippi. He became fascinated with electricity and nurtured that interest until he became his Chicago neighbors' favorite radio repairman by the age of 13.

His technical interests were formally pursued at Illinois Institute of Technology in Chicago, where he earned a degree in physics. Although one of his high school teachers told him that he would never become a successful engineer, he didn't listen. To help support himself through college, he made customized high-fidelity equipment. He conducted research at the Institute for 10 years; however, he always had a business eye and decided to launch his own business interests with $1,000 in capital. The fledgling company started in his basement. His first major contract was with the Navy, making loudspeakers.

Through the years, Sonicraft grew as its contracts with various military branches and Federal Aviation companies increased. After 15 years in business, the reliability and quality of the products produced by Sonicraft led to the signing of a $268 million contract with the Air Force in 1982. Sonicraft agreed to design and manufacture very low frequency receivers that will operate even after exposure to X-rays and gamma radiation from a nuclear attack. The agreement is a multiphase operation that ran through 1989.

Jones — the major shareholder in Sonicraft — set the goal to make it a billion-dollar company by the early 1990s, putting his company in the league with the Fortune 500s. Although the company's basic work involved manufacturing, in the future it will seek to increase its research and development capability and strive to make yet another dream come true.

Emma Littleton

Electrical Engineer

Fresh out of high school, Emma Littleton had one clear goal in mind — to become a top-notch secretary.

She started as an enthusiastic and inquisitive junior clerk at Indian Hill Laboratory in Naperville, Illinois, and soon was promoted to a secretarial job. The technical work going on around her was intriguing, and after learning about the work in her department — the development of an expanded and improved telephone switching system called No. 4 ESS — she decided that she wanted to become an electrical engineer. Technical staff were impressed by her enthusiasm and obvious aptitude to grasp technical information.

With encouragement, she enrolled in Tennessee State University, a traditionally African American engineering school, where she excelled. She earned an engineering degree with top honors and a cumulative grade point average of 3.8. During her summer vacations she continued to work at Indian Hill, but in a technical capacity. A Bell Labs staff member was her senior project advisor. He was on leave from his regular work assignment and teaching at Tennessee State University. Today Ms. Littleton is a full-time member of Bell Labs' professional staff. Her career in engineering had been delayed four years because she initially decided to be a secretary (because that was the only thing she knew). In time, she grew restless and a bit dissatisfied. That led her to her real career choice.

Bell Labs was so enthusiastic that they selected her to study for a year under the Bell Labs Graduate Studies Program, which permits promising staff members to work for an advanced degree in their specialty with full tuition and expenses underwritten by the company.

Ms. Littleton's career was successfully launched after receiving the right exposure to career opportunities and the right counseling, which she should have received in high school. Fortunately, engineers at Indian Hill and staff at Tennessee State University were able to help her realize her full potential.

Dr. Walter E. Massey
Physicist

Dr. Walter Massey

Theoretical Physicist and former Director,
National Science Foundation

Dr. Walter Massey was appointed as Director of the National Science Foundation by President George Bush in 1990, a position he held until January 1993. His position prior to that appointment was Vice President of the University of Chicago for Research and for Argonne National Laboratory. He served as President of the American Association for the Advancement of Science (AAAS), the world's largest association of professional scientists, in 1989. He was elected President of the American Physical Society in 1990. He also serves on the Physics Advisory Committee of the National Science Foundation, the National Academy of Sciences Advisory Committee on Eastern Europe and the former USSR, and the Board of Directors of AAAS.

In 1979, at the age of 41, Dr. Massey became Director of Argonne National Laboratory (ANL) in Argonne, Illinois (25 miles southwest of Chicago), which is operated by the University of Chicago. ANL is one of the nation's top energy research laboratories. In addition to its main site near Chicago, there is the Idaho Engineering Laboratory near Idaho Falls. ANL employed 2,000 scientists and engineers among its more than 5,000 employees while Dr. Massey was Director. ANL operates seven experimental nuclear reactors, including the nation's first nuclear breeder reactor which started producing electricity at ANL's site in Idaho Falls. Although nuclear energy is a primary function of the Laboratory, other energy sources researched at ANL include perfecting battery powered automobiles, making synthetic fuels, and better utilizing solar energy.

Dr. Massey has a long association with the University of Chicago. He first joined the faculty in 1968 after his graduate studies. When he was first appointed Director of ANL, he was also appointed Professor of Physics at the University. Prior to becoming Director, Dr. Massey was at Brown University where he was first an associate professor of physics and later appointed Dean of the College.

A native of Hattiesburg, Mississippi, Dr. Massey entered college from the 10th grade. He is a Morehouse College graduate with a B.S. degree in physics and mathematics and received his master's degree and doctorate in physics from Washington University in St. Louis, Missouri. He was a postdoctoral appointee at Argonne from 1966 to 1968 and a consultant there from 1968 to 1975. His research interest was in the theory of strongly interacting systems of many particles, with particular emphasis on low temperature properties of quantum liquids and solids.

Dr. Massey was recently appointed Senior Vice President and provost of the University of California.

Dr. Warren Miller

Nuclear Engineer

Dr. Warren Miller developed an interest in mathematics and science in grade school and high school. A West Point graduate, he has a B.S. degree in Engineering Sciences with an area of interest in nuclear engineering and nuclear reactor theory. He obtained the master's and Ph.D. degrees from Northwestern University in nuclear engineering.

Dr. Miller currently has a joint appointment as an Associate Director at Los Alamos National Laboratory and as a Dardee Professor (endowed chair) in the Nuclear Engineering Department at the University of California, Berkeley.

Los Alamos National Laboratory is one of the largest research laboratories under contract to the U.S. Department of Energy. Prior to joining the technical management staff at Los Alamos, he was a Group Leader for the Transport and Reactor Theory Group, in the Theoretical Division of the Laboratory. His research interests include neutral and charged particle transport theory, fluid dynamics, radioactive waste management, and radiation shielding. Concurrent with his position at Los Alamos, he serves as a consultant to Sargent and Lundy, and to Argonne National Laboratory.

He has published numerous papers and excelled in the area of computer solutions to partial differential equations, specifically, solutions to the neutron transport equation. He was invited to coauthor a book entitled *Computational Methods in Neutron Transport Theory*, which will be published by Wiley Interscience. His work has led to the development of a general theory that allows a comparison of all methods suggested for accelerating the iterative processes used in neutron transport computer codes. This theory makes it possible for new methods to be developed and compared with existing schemes.

In addition to his research interests, Miller enjoys teaching and has served as a visiting professor of nuclear engineering at Howard University. He also developed and taught a course at Northwestern entitled "Science, Technology, and the Black Experience." One of the stated objectives of the course was to promote thinking in aspiring scientists and engineers toward application of their skills to the development of African American communities at home and abroad.

Cordell Reed

Mechanical Engineer

Although a mechanical engineer by college education, Mr. Cordell Reed has become a nuclear expert and Senior Vice President of Nuclear Operations at Commonwealth Edison of Chicago, through work experience and on-the-job schooling. He started as an engineer at one of Edison's coal-fired generating stations. After seven years, he switched to a nuclear-powered station. Commonwealth Edison decided to invest in the highly motivated Reed and spent approximately $100,000 to provide him a background in reactor physics, health physics, and nuclear engineering.

Mr. Reed knows the business inside and out. He has been involved in various aspects of work at nuclear power stations, namely design, construction, and operations. It is second nature to him, although engineering was very foreign to him while growing up on Chicago's South Side. The decision to study mechanical engineering at the University of Chicago began the change. Now, with ease, he evaluates the proposals, generates the specifications, and purchases reactors, turbine generators, and other equipment with Commonwealth Edison's multi-billion-dollar budget. He has the final word on top-level decisions concerning six nuclear power plants.

Reed is definitely a pro-nuclear advocate. He has concluded from first-hand experience that the nuclear industry is safe and that nuclear energy is critical for the United States to meet its energy demands. Often, he finds himself presenting the facts to the public and embroiled in debates over nuclear safety. According to Reed, "Without nuclear power, there will be a shortage of energy which will drastically increase unemployment." Having known the miseries of low income and poverty, Mr. Reed can appreciate the negative impact that a devastating energy crisis could have on low-income families.

Dr. John B. Slaughter

President, Occidental College, and former Director of the National Science Foundation

Dr. John Brooks Slaughter received his academic training in electrical engineering and engineering physics, and his research specialty is in the field of digital control systems theory and applications. Although he began his career as an electronics engineer in industry and later in government, he has always been a part of the academic community. Throughout his career, he has been active in national efforts to involve minorities in engineering and science.

Dr. Slaughter is currently President of Occidental College in Los Angeles, California, a post to which he was appointed in 1988. Prior to that, he served as Chancellor of the University of Maryland from 1982 to 1988.

Dr. Slaughter served as Director of the National Science Foundation from 1980 to 1982, a post he was nominated for by President Jimmy Carter. The National Science Foundation is the major U.S. government agency that supports basic research in the physical and life sciences. NSF also supports science education and applied sciences and is in charge of several major laboratories, such as the National Optical and Radio Astronomy Observatories. Dr. Slaughter served an earlier tour of duty at NSF, also at the request of President Carter, as Assistant Director of Astronomical, Atmospheric, Earth, and Ocean Sciences from 1977 to 1979. In this position, Dr. Slaughter was responsible for five NSF divisions — Earth Sciences, Ocean Sciences, Astronomical Sciences, Atmospheric Sciences, and Polar Programs.

In 1979, between his two appointments at NSF, Dr. Slaughter was Academic Vice President and Provost of Washington State University in Pullman, Washington.

Before going to NSF in 1977, Dr. Slaughter was Director of the Applied Physics Laboratory and Professor in the Department of Electrical Engineering at the University of Washington at Seattle. As Laboratory Director since 1975, he was responsible for the direction and management of a research and development program in ocean and environmental sciences and engineering. He initiated new programs in energy resource conservation and development, geophysics, environmental acoustics, and bioengineering at the Laboratory. Under his direction, the staff of the Laboratory, a leader in the fields of underwater acoustics, underwater vehicles, and physical oceanography, grew from 180 to 240 people.

Dr. John B. Slaughter
Electrical Engineer

Prior to going to the University of Washington, Dr. Slaughter was Head of the Information Systems Department of the Naval Electronics Laboratory Center (NELC) in San Diego, California. In that capacity, he was responsible for the management of a 200-person staff engaged in the design and development of Navy command and communication systems. Under his direction there, a major new emphasis in biomedical engineering was started. He was named Scientist of the Year at NELC in 1965, where he served from 1960 to 1975.

Earlier in his career, from 1956 to 1960, Dr. Slaughter was employed by the Convair Division of General Dynamics Corporation in San Diego where he worked on the development of missile flight instrumentation and telemetry equipment.

Dr. Slaughter was born in Topeka, Kansas, in 1934 and earned a Bachelor of Science degree in electrical engineering at Kansas State University in 1956. He earned a Master of Science degree at the University of California at Los Angeles (UCLA) in 1961. He also was awarded a Doctor of Philosophy degree in engineering science at the University of California at San Diego in 1971.

Dr. Slaughter has written widely in his field and is a member of several professional organizations including Eta Kappa Nu, the honorary electrical engineering society; Tau Beta Pi, the honorary engineering society; and was elected to the National Academy of Engineering in 1982. He has been editor of the *International Journal of Computers and Electrical Engineering* since 1977. He is also a Fellow of the Institute of Electrical and Electronic Engineers.

He served from 1968 to 1975 as Director and Vice-Chairman of the Board of the San Diego Transit Corporation, specializing in policy matters related to transit planning and technology. He was a member of the affiliate engineering faculty at San Diego State University from 1963 to 1965 and established graduate courses in discrete and optimal control systems. He was appointed to the San Diego Chamber of Commerce Energy Task Force in 1974 to advise on technological approaches to energy conservation.

Dr. Slaughter has been active in efforts to encourage minorities to pursue careers in science and engineering, and he has played a strong role in urging educational institutions, industry, and government to take more aggressive steps to improve opportunities for minorities in those fields. In 1976, he was appointed a member of the National Academy of Engineering Committee on Minorities in Engineering. In 1983 he served as a member of the National Science Board Commission on Pre-College Education in Mathematics, Science, and Technology. In 1987, the *U.S. Black Engineer* magazine named him its first "Black Engineer of the Year."

Howard Smith

Computer Research Manager

Howard Smith is a computer scientist and President of Clarity Software, Inc. Mr. Smith and a group of computer veterans founded Clarity Software in January 1990 to design, develop, and market personal communications software products for UNIX workstation platforms. These personal communications products have significant value added, both in function and in multimedia document technologies, and are mail-centered. Clarity's initial product is called CLARITY and is composed of a Compound Document Editor, spreadsheet, presentation graphics, and Advanced Mail components. This product will be followed by other personal communications software.

Previously, Mr. Smith was employed by Hewlett-Packard Corporation. Responsible for the development of operating systems and process systems units, he supervised 200 employees for Hewlett-Packard's Computer Systems Division in Cupertino, California. The development of computer equipment is a very competitive and dynamic business, and Howard Smith is one of the managers who helped Hewlett-Packard, a leader in computer design, maintain its competitive edge.

Enthusiastic about his work, Smith considers himself to be very people oriented. Some might find this surprising, since the computer scientist is often stereotyped by others as cold and more oriented to machines than to people. The job as a manager requires long hours that must be divided between the research aspects and the people performing the research. As manager, Mr. Smith must assure that ideas are developed within a given budget and completed within a specified schedule. Any problem that threatens the research project must be resolved by him and the staff working in the division. Some of the problems faced are technical, but many are more related to business and planning.

Mr. Smith is a graduate of Los Angeles State College and San Jose State University. He received a bachelor's and a master's degree in mathematics. He attributes part of his career success to enjoying what he does. He says that it is important to set both short-range and long-term goals so that you can evaluate your progress and redefine your goals as necessary. Reaching your goals creates self-confidence, another important part of succeeding in an organization.

Some of Howard's spare time is spent working with high school and college students helping them prepare for technical careers. He is a member of the advisory board of Project Interface in Oakland, California. This program is community-based and provides tutorial services and career counseling to student participants.

Dr. Arthur B. C. Walker, Jr.

Astrophysicist

Dr. Arthur Walker is a Professor of Applied Physics at Stanford University. His research specialties are solar and nonsolar X-ray astronomy, concentrating on the study of high-temperature, low-density astrophysical plasmas using space-borne instrumentation. He has participated in numerous investigations using sounding rocket and satellite vehicles. At Stanford, he developed instruments for obtaining very high resolution, highly sensitive images of the solar atmosphere at X-ray and extreme-ultraviolet wavelengths, using the new technology of multilayer interference reflection coatings with normal-incidence-reflection optics. These instruments were flown on sounding rockets to obtain the first high-resolution X-ray images of the Sun using this technique. An experiment proposed by Dr. Walker, "Ultra High Resolution XUV Spectroheliograph," was selected by NASA for development and flight as an attached payload on the Space Station Freedom.

Arthur B. C. Walker, Jr., received his Ph.D. in physics from the University of Illinois in 1962. His initial research was in nuclear and particle physics. In 1965 he joined the Aerospace Corporation and began working in solar physics and upper atmosphere physics, specializing in the study of solar X-rays. He was Director of the Space Astronomy Project at Aerospace Corp. from 1972 to 1974. In 1974, he became Associate Professor of Applied Physics at Stanford, where he is now Full Professor, Associate Director of the Center for Space Science and Astrophysics, and Director of the Stanford Student Astronomical Observatory. At Stanford, he has also served as Associate Dean of the Graduate Division, Chairman of the Astronomy Program, and Director of the John Wilcox Solar Observatory.

In 1986, Dr. Walker was appointed a member of President Reagan's commission that investigated the Space Shuttle Challenger accident. He has also participated in numerous NASA, NSF, and other advisory committees and has been active in the NAACP.

Dr. William Wiley

Bacteriologist and Laboratory Director

Dr. William R. Wiley is director of Battelle's Pacific Northwest Division and a Senior Vice President of Battelle Memorial Institute — an independent, worldwide, science-based organization dedicated to "putting technology to work." Battelle is the world's largest not-for-profit research organization.

As the principal Battelle executive in the Northwest, he is director of the U.S. Department of Energy's Pacific Northwest Laboratory, a multiprogram national laboratory operated by Battelle since 1965.

Dr. Wiley is responsible for Battelle business activities in the Northwest, including research, development, and technology commercialization at Battelle's research complex in Richland, the Marine Sciences Laboratory at Sequim, and the Battelle Seattle Research Center.

A member of the Battelle staff since 1965, Dr. Wiley served as Director of Research at the Richland laboratories between 1979 and 1984. Earlier assignments include management positions with the Biology Department and the Cellular and Molecular Biology research section.

Dr. Wiley earned a bachelor's degree in chemistry from Tougaloo College, Mississippi. Studying under a Rockefeller Foundation scholarship, he earned a master's degree in microbiology from the University of Illinois-Urbana in 1960. His doctorate degree in bacteriology was awarded by Washington State University, Pullman, in 1965.

In addition to his role at Battelle, Dr. Wiley is an associate professor of bacteriology at Washington State University in Pullman, Washington. He came to the great Northwest to find success and prosperity. He wanted the opportunity to make a contribution to his discipline. Through hard work and dedication to his profession, 20 years later he has been able to do just that. The many years of educational preparation and hard work paid off.

He has authored numerous publications in his field. His research includes microbial metabolism, particularly the factors which control intracellular pool formation and membrane transport of amino acids and sugars in microorganisms and mammalian cells; development environmental engineering; biotechnology; geoscience; and analytical chemistry.

Dr. Wiley has served as a George Washington Carver Lecturer at Tuskegee Institute, Alabama, and he lectures at African American universities as part of the Black Executive Exchange Program. He holds an adjunct faculty appointment with Washington State University as an associate professor of microbiology.

Astronaut Franklin R. Chang-Diaz, mission specialist, prepares to input data on the personal general support computer on the middeck of the Space Shuttle Atlantis.

Planning
Careers in
Science and
Technology

STS-47 Mission Specialist Dr. Mae Jemsion examines the interior of the Spacelab-J laboratory module, installed in the cargo bay of the orbiter Endeavour.

Chapter IV. Planning for Careers in Science and Technology

Choosing a career requires examining your interests, abilities, qualifications, and goals and your decision to invest the necessary time and effort. It also means knowing about the requirements, responsibilities, and rewards of various careers. It is much too important a decision to leave to chance! Selecting a satisfying career may seem like an overwhelming task, but the selection process can be easier through careful planning and guidance.

If you believe that a career in a science, engineering, or technical field may be in your future, begin preparing today. This means developing a plan of action. First, analyze your interests, abilities, and aptitudes. Consider school courses you like and dislike. Hobbies, sports, extracurricular activities, and your personal characteristics are factors to be considered.

Take a closer look at those fields in which you already have some interest. Overviews of scientific and technical fields are supplied in Chapter II. However, since it is not possible to give more than a brief look at each specialty field, if an area such as computer science or nuclear engineering appeals to you, here are some suggested ways to find out more.

1. Go to the library and locate books, magazines, and journals in your subject area. If you are currently a high school student, many of the more advanced books and journals in science and engineering may appear very complex. Don't be intimidated; there will be plenty of time to learn the terminology and the mathematical techniques. Assess your interest in the subject matter by reviewing books and magazine articles on a variety of levels, from the introductory levels of *Discover* and *Scientific American* magazines, to the intermediate levels of such publications as *Physics Today* and *Aerospace America*, and even to the advanced levels of *Journal of Chemical Physics* or *The Astrophysical Journal*.

2. Your parents and adult friends can be a great help in the development of career plans, especially if they work in fields related to those in which you are interested. Ask questions about your parents' careers. Friends of your family who are employed in occupations related to your field of interest can be helpful in your exploration.

3. Discuss your career goals with your teachers and guidance counselor. They can provide valuable advice on the best way to achieve your goals. They can also help you find literature pertaining to careers and information about summer and part-time jobs.

   Literature pertaining to careers is usually located in the guidance office and the library of your school. Publications such as the *Dictionary of Occupational Titles* and the *Occupational Outlook Handbook* and other career guidance materials are useful to your career search.

   Your guidance counselor can help you match your qualifications with appropriate career goals. At the beginning of each school year, you, your parents, and your counselor should review thoroughly your high school courses with future educational plans, aspirations, and tentative career goals in mind.

4. Request more comprehensive career information from technical organizations associated with the specific fields in which you are interested, such as those listed in *Career Opportunities in the Sciences* (see Appendix). Your counselor can help you locate and review these materials. They include information about:
   - what a person does on the job
   - what abilities and interests are required by the job
   - what types of education and training are required
   - what the working conditions are like
   - what future job opportunities are predicted to be.

   As you read through this material, match your abilities, skills, and interests to the jobs that seem appealing. A list of organizations and societies that relate to your career interests can be obtained through the school guidance office.

5. Talk to people working in the field in which you are interested or people in a closely related field. They can give you first-hand information on what the work is *really* like; also, they can relate their experiences in the college educational process. They can also advise you on proper work and study habits and choice of educational institutions. If possible, try to visit their work areas so that you can see firsthand the work environment and the types of jobs various employees perform.

6. Request catalogs and other information from colleges you might be interested in attending well before your senior year of high school. Be sure to take note of requirements for admission, estimated costs for tuition and fees, room and board, etc., and opportunities for student financial aid.

   Information about colleges and military academies, vocational and technical schools, apprenticeship and cooperative education programs, and military services may also be found in your high school guidance office. This information may help you with the expenses of education or training beyond high school graduation.

7a. Try to get a summer job or part-time job in a field related to your interest. Such jobs not only provide a source of income, they also give you firsthand experience in a scientific or technical occupation and allow you to observe professional scientists, engineers, and technicians at work. Many government and industrial organizations offer paid summer apprenticeship programs for high school students. Your employers can also offer information about their particular jobs and related occupations. They can evaluate your work performance and the interest you have displayed in the job.

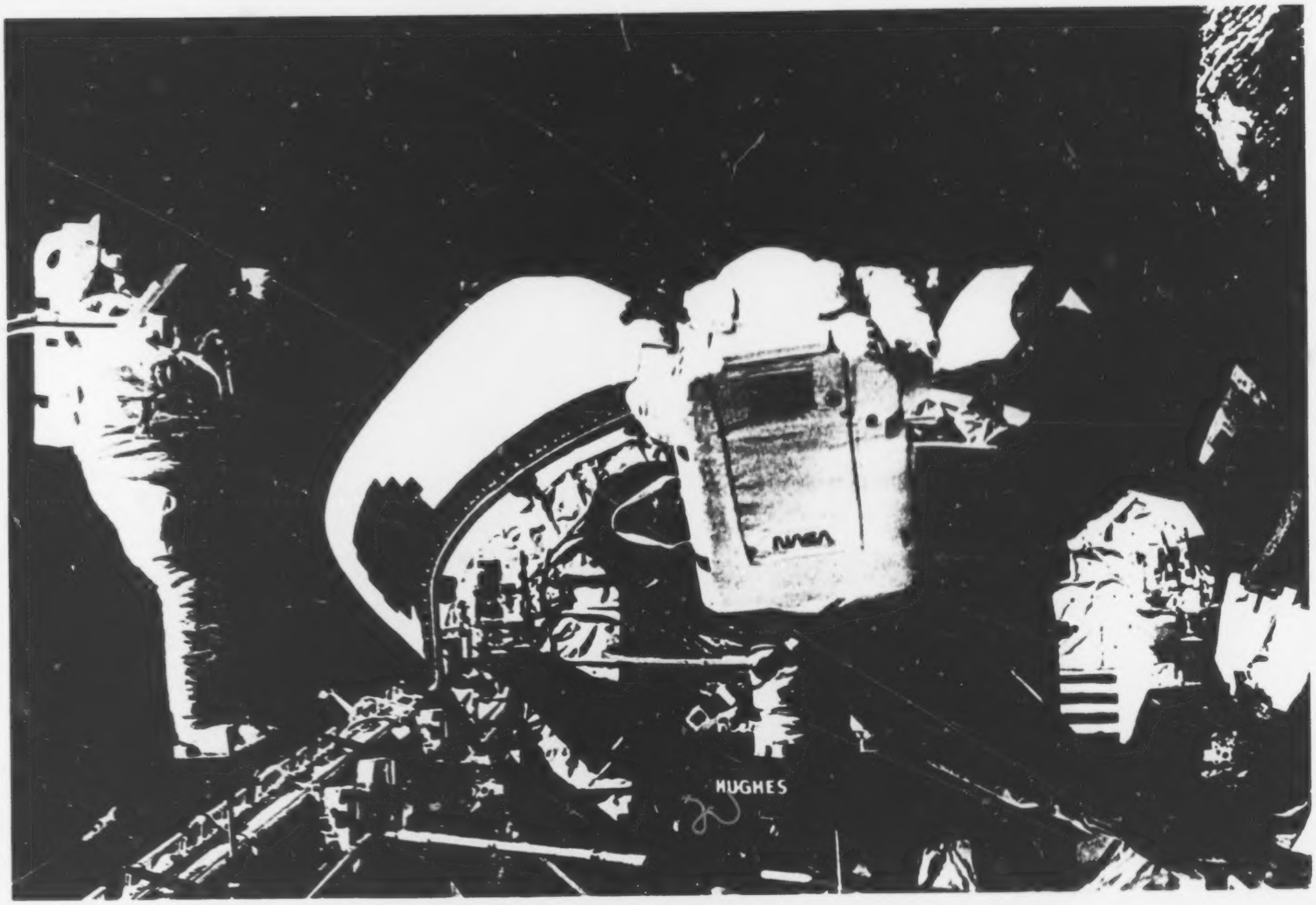
   A second, very important step is to take all the available high school courses related to your potential career goals. As is emphasized throughout this book, professional and technical occupations in science and technology require specialized education and training beyond the high school level. To be qualified to apply to these programs and to pursue them efficiently once admitted, you must be aware of the entrance requirements for college curricula in your field of interest and acquire the necessary prerequisites while in high school.

   The National Technical Association (NTA) has, as one of its goals, the encouragement and support of minority youth in their pursuit of scientific and technical educations and eventual careers in these fields. Members of NTA are available for consultation on any of the above topics. In addition, other professional organizations, such as the American Association for the Advancement of Science, have subgroups concerned with scientific and technical education and career advancement. Some available publications and videotapes are listed in the Appendix.

   The world of scientific and technical careers presents many diverse opportunities for the prepared person. Therefore, spend the years while you are in high school laying a good foundation for that world. Take advantage of every opportunity to get the training and experience you will need for your selected career. Advanced planning will prepare you to qualify for a career that is satisfying and rewarding.

7b. Try to participate in a special summer education program that offers some science, math, and/or engineering exposure. You may contact the NASA Education Division, Code FEE, Washington, DC 20546, (202) 358-1518; the Department of Energy, Office of University and Science Education Programs, Code ER-80, 1000 Independence Avenue, SW, Washington, DC 20585, (202) 586-8949; or the Naval Research Laboratory. The Naval Research Laboratory offers cooperative education summer and part-time employment to students, and also participates in DoD's Science and Engineering Apprentice Program. For further information, contact Naval Research Laboratory, Human Resources Office, Code 1812, Washington, DC 20375-5320, (202) 404-8305.

Educational Requirements for Careers in Science and Technology



The successful capture of the Intelsat VI satellite, during the first mission of the Space Shuttle Endeavour *in May 1992. Left to right, astronauts Richard J. Hieb, Thomas D. Akers, and Pierre J. Thuot have handholds on the satellite.*

Chapter V. Educational Requirements for Careers in Science and Technology

Careers in science, engineering, and technology emphasize basic knowledge and skills in science, mathematics, and technical subjects. The extent to which you master these three areas will help determine your selection for entry-level positions and how quickly you advance in your work assignments. There are places for men and women who have different levels of competency in all three of these subject areas.

Chapter II provides descriptions of a wide variety of scientific and technical fields and occupations. Nearly all college curricula in science and engineering are based on the same fundamental principles and have, therefore, nearly the same basic educational prerequisites. In particular, at the high school level, the necessary preparation for all fields includes *mathematics* (algebra, geometry, trigonometry, and any other available courses), and *science*, including as a minimum *biology*, *chemistry*, and *physics*.

It is difficult to overemphasize the importance of taking these basic mathematics and science courses as early as possible and doing as well as possible in them. These courses lay the necessary foundation for the more advanced science and mathematics courses that form the basis of college curricula in science and engineering. These advanced courses are normally taken in the freshman and sophomore years of college. Course work in *computer science* is increasingly important and should be pursued to the extent available. *Communications* skills also are valuable to scientists and engineers. Therefore, courses that develop one's reading, writing, and speaking skills are essential.

Chemists, physists, and biological researchers are utilized in various NASA, Department of Energy, and other federal agency laboratories.

Science and Your Career

Nearly all scientists, and most engineers, must be familiar with the elements of three basic sciences: biology, chemistry, and physics. You will need to study different amounts and kinds of science courses for different occupations. For some jobs, such as skilled trades like welding, high school science courses are sufficient. The training of engineering and science technicians usually includes science courses like those offered at technical institutes or community colleges. Many professions require only one or two years of college science courses. Some careers demand four years of college work in science while others require several additional years of graduate study.

Even if you do not plan to be a scientist, a knowledge of science will help you in many other careers. A good understanding of scientific principles may lead to a better understanding of the world. With a background in science, you will be able to discuss more intelligently and make better decisions regarding community issues. For example, an understanding of chemistry and biology will help you decide upon systems to control air and water pollution. A knowledge of science will help you enjoy life in a highly advanced technological society.

Mathematics and Your Career

Mathematics is important to you every time you buy a record album, a pizza, or gas for your car. You will use some mathematics throughout your entire life, regardless of your chosen career. Mathematics is a science and is sometimes referred to as the most exact science. Mathematics is essential to scientific, engineering, and technical careers. It is a precise and universal language understood all over the world. Actually, it would be difficult to find any type of work where mathematics is not useful. The mathematics you study in high school is used in many career fields.

Different occupations require varying amounts and kinds of mathematics courses. For some jobs, high school vocational math courses are sufficient. These courses will help you prepare for apprenticeship training required for many skilled trades. Skilled machine tool operators rely upon their mathematical backgrounds to set up their machines to precise dimensions. To prepare for careers as technicians, individuals will be expected to complete successfully courses offered on a level beyond those of high school vocational math. If you aspire to scientific or engineering careers, you must complete advanced math courses in high school. These courses will prepare you for college-level mathematics. Scientists and engineers must complete three to four years of college-level math. Additional years of graduate study are often required.

The modern trend in scientific and technical careers requires more and more emphasis on mathematical and related competencies, such as computer science. Statistical and mathematical models are used to solve nonmathematical problems. The person skilled in this discipline probably will find favorable employment opportunities in future years. Even if you do not plan to continue studying math after high school, it is a good idea to take all of the courses available to you. Some day you may change your mind about a career. At that time, you may be required to complete math courses you have not taken.

Emphasis on Technical Skills

Technical skills are also important in training for scientific and technical careers. Your choice of a career field and your level of aspiration in that field will be influenced by the technical skills you demonstrate. These skills include hand-eye coordination and quickness and ease in using your hands to manipulate objects. Technical jobs include drafting, electrical wiring, microwelding, and polishing lenses. Scientists, engineers, and technicians use different technical and manual skills, but in general the relative importance of technical skills is greatest for the technician and least for the scientist. As is true with science and math courses, the kinds of technical subjects (vocational and industrial arts courses) you select will be determined by your career interests.

Other Important Courses

Although special emphasis has been placed throughout this book on science, mathematics, and technical courses, a well-rounded high school education is essential. A well-rounded program gives the flexibility to respond to new, and sometimes unexpected, opportunities. You must be able to communicate your thoughts simply and clearly. Even the most brilliant engineer or scientist must be able to explain the significance of original ideas, if the ideas are to be accepted. Therefore, English literature, grammar, speech, and composition courses must be completed with above average grades. Effective oral and written self-expression is crucial to success in any career field. Courses in history, civics, economics, political science, geography, sociology, psychology, and foreign languages will stimulate your thinking and expose you to new concepts and ways of living. Foreign languages are recommended because international cooperation and competition have become important aspects of modern science and technology. For example, many scientific papers are published in foreign languages.

Students are encouraged to take a wide variety of advanced subjects so that they will be prepared for several possible career fields. Courses in manual skills (woodworking, basic electricity, typing, and mechanical drawing) will help you recognize your aptitudes for technical work. They will acquaint you with material covered in college courses. Skills taught in a typing course will be appreciated when college paper assignments are due. If time permits, a shorthand course will be a tremendous asset to a student taking notes during class lectures and laboratory periods.

Scientific and engineering careers require college degrees. To gain admission to colleges, students must earn good grades in college preparatory courses. These normally include English, mathematics, natural sciences, social sciences, foreign language(s), and appropriate electives. Make sure that you have completed all required courses for high school graduation and college entrance before you select elective courses. Grade point average, class rank, scores on standardized tests, recommendations, and participation in extracurricular activities are considered by selection committees at colleges.

Extracurricular activities are an important part of a well-rounded high school program. Participation in science fairs and in science, mathematics, or computer clubs are especially relevant because they give you an opportunity to apply what you have learned in classes and to explore areas not covered in the formal course work. Sports, student government, clubs, school publications, and programs offered through the community provide enjoyable opportunities to meet new friends and explore interests. They are evidence of an active, interested student. Admission committees at colleges and summer or part-time employers usually study a student's academic record and participation in extracurricular activities.

Looking Ahead to College

It is important to review the entrance requirements of several colleges before you plan your high school curriculum. Also, it is important to plan your high school courses with the assistance of your guidance counselor, teachers, and parents. College catalogs and admissions officers at colleges of your choice will provide specific details about their requirements. Knowing entrance requirements will provide a basis for the selection of the most appropriate courses. This will prevent you from being required to complete additional courses prior to admission to college. It also will prevent your rejection by a college of your choice on the basis of inappropriate or insufficient course work.

Most colleges require scores on standardized college entrance examinations. This information is found in college catalogs. The Scholastic Aptitude Test (SAT) and the American College Test (ACT) are the names of these entrance examinations. Check with your counselor for the dates of these tests and procedures for registering to take them.

Some school systems offer accelerated students the option of taking Advanced Placement examinations. Certain colleges offer college credits to students who distinguish themselves with high scores on these tests. In this way, advanced students may earn college credits while in high school. This reduces the time and expense required to earn a college degree and allows students to register for additional course work of particular interest. College catalogs and guidance counselors are sources of information about this opportunity.

Selecting a College

Choose your college or university carefully. Gather information about several colleges before you decide upon your favorite choice. You should apply to several colleges in case you are not selected by the one first on your list. Check the advantages and disadvantages of each school with your tentative career goals in mind. It is a good idea to begin the application process during the summer months preceding your senior year in high school. This will give you a head start over the thousands of seniors also applying to the schools you select. Perhaps you will know of your acceptance or rejection by Christmas. This will be a relief and reduce the tension and suspense of waiting to learn your status. It will also give you an opportunity to apply to other colleges if you are not accepted.

Factors to Consider When Selecting a College

Perhaps the most important factor in selecting a college is the curriculum offered, in terms of its compatibility with your career goals. However, a number of other factors also need to be considered, such as available housing, accreditation, entrance requirements, cost of tuition, fees, room and board, financial assistance programs, life style of the students, location, travel and social expenses, size of the college, as well as class size in basic courses and student faculty interaction.

Since the selection of a college is a major decision in your life, and since it is often difficult to transfer from one college to another after beginning your college career, you are wise to gather information from your family, your guidance counselor, the admissions officer at the college, college catalogs, and friends who have attended the college. Visits to the campus are suggested. Remember, sometimes compromises and alternate choices must be made, so be flexible!

Cost?

The cost of an education to prepare for scientific and engineering careers will vary. High school graduates with good grades and a sincere interest in a college education usually can find ways to finance the costs of earning a college degree. Costs are determined by such factors as choice of institution, choice of curriculum, and your eligibility for and acceptance of scholarships or other forms of financial assistance. Scholarships, loans, grants-in-aid, fellowships, work-study programs, part-time jobs, and cooperative education programs are available to qualified students. Guidance counselors can assist you in locating sources of financial aid. Several books on scholarships are available in libraries and in the guidance office. This information changes and requires planning and correspondence to ensure your eligibility for funds. The extra effort may pay off in thousands of dollars for your education.

Many colleges offer cooperative education programs. Students in these programs alternate periods of college study and work at job sites. This opportunity provides practical work experiences which bring "life" to classroom theory, in addition to helping finance your college education. Practical on-the-job experiences will help you decide if you really enjoy the work. These experiences may reinforce your career plans, or you may decide to change your plans. Valuable contacts are established for permanent employment after college graduation. Also, the relevant experience may qualify you for a higher entry-level position than if you had only the formal college course work.

Basic College Courses

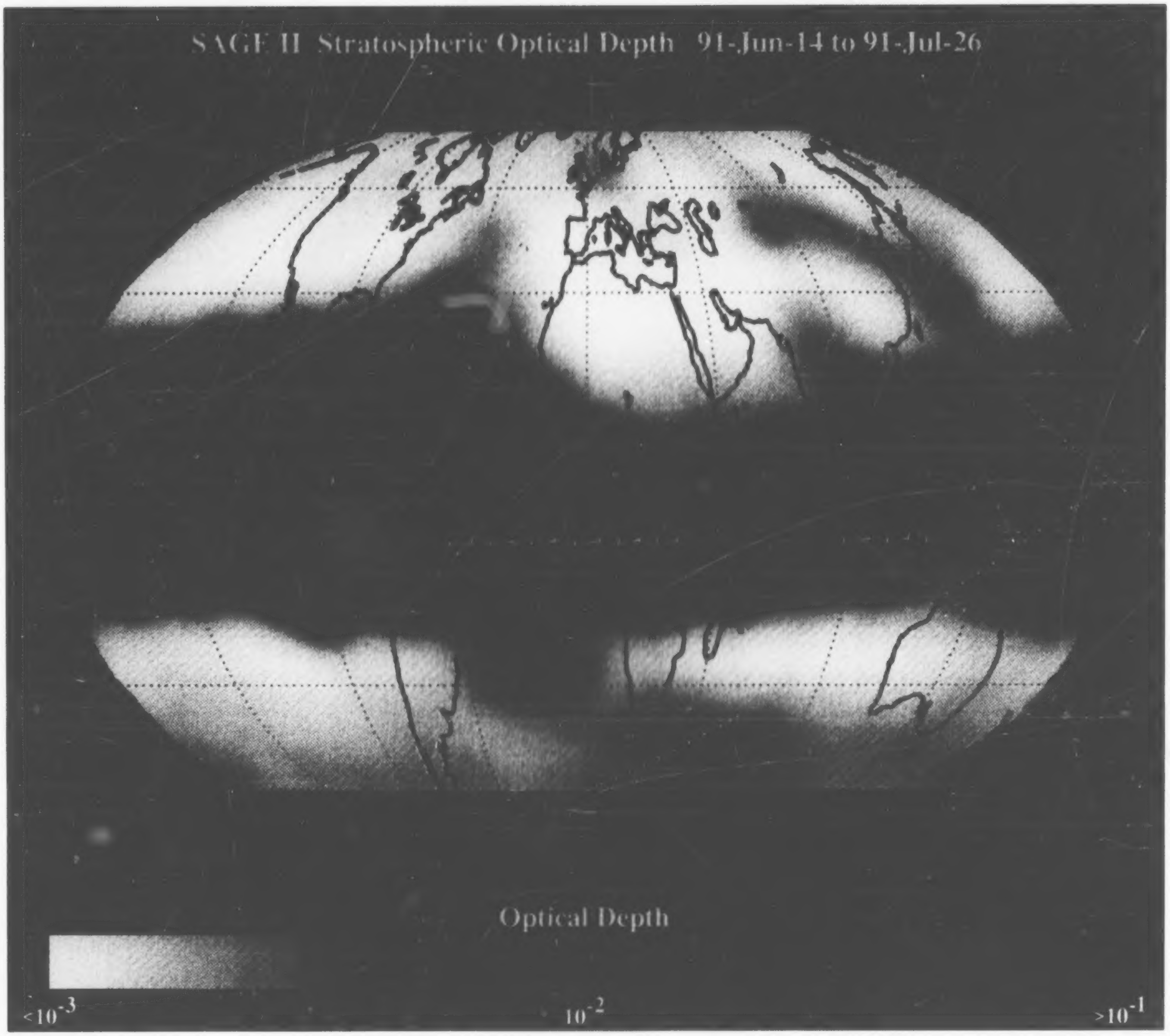
Undergraduate programs leading to degrees in the life sciences, physical sciences, mathematics, or engineering are the foundations for most careers in science or engineering. Knowledge of basic principles will enable you to adapt to the continually changing priorities and requirements that are characteristic of occupations in industry, government, and academic institutions. This understanding provides a solid foundation for comprehending the ever-expanding body of knowledge in the fields of science, engineering, and technology. A scientist or engineer completes a basic undergraduate curriculum in the chosen field and then becomes more skilled through work experiences in research and development, and through additional courses. Learning new techniques, cooperating with new people, and working in different environments provides challenge to these professions.

At the college level, it is best to avoid over-specialization too early. In the real world, few professionals end up doing exactly what they had planned to do when they entered college. The broader the educational base, the wider the choice of occupations upon graduation. As mentioned, the first two years of the college curricula for most fields of science and engineering are similar, with emphasis on mathematics (including, typically, three semesters of calculus and one of differential equations) and college-level courses in biology, chemistry, and physics. At the junior and senior levels, the curricula become more specialized, but there is still the opportunity, by means of elective courses, to obtain a broad education.

Curriculum

Regardless of the field of engineering a student elects to study, initial emphasis in all departments is on the fundamentals of engineering education. During the freshman and sophomore years, all engineering students take general courses in calculus, chemistry, physics, English, social studies, humanities, physical education, and introductory engineering courses. In your junior year you will begin taking specialized engineering courses in your major department. In addition to these specialized courses, you will be able to select elective courses in engineering, related sciences, business, and liberal arts.

Thus, although attention is given to specialization, instruction is focused primarily on fundamentals and the application of these fundamentals to engineering analysis and design problems which are essential to professional growth and lifelong learning in this area of rapid advancement of knowledge.



After centuries of dormancy, Mt. Pinatubo in the Philippines (15 N, 121 E) erupted violently in mid-June 1991, producing a large quantity of aerosol particles in Earth's stratosphere. The impact of this eruption is being monitored by the SAGE II (Stratosphere Aerosol and Gas Experiment II) satellite instrument from NASA Langley Research Center. SAGE II measurements can be used to produce near-global maps of the stratospheric optical depth, which is a measure of the total amount of aerosol particles in the stratosphere overhead. The map shows that within a month following the Pinatubo eruption, a dense belt of material had encircled the globe in the tropics. Optical depths in the tropics had increased by about a factor of 100 compared to measurements taken prior to the eruption. Now one year after the eruption, SAGE II data show high particle levels nearly everywhere around the globe. Based on observations of previous eruptions, particle levels are expected to remain high for several more years.

Steps to Scholastic Success

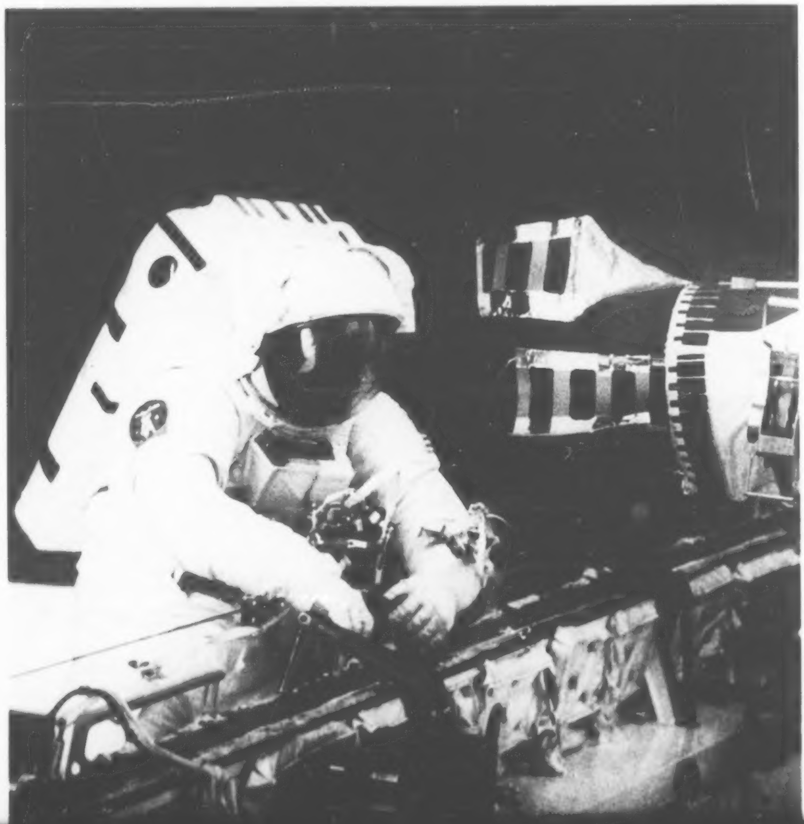
Careers in science, engineering, and technology require success in higher learning. The most widely accepted criterion of academic success is high grades in the course work completed. Grades often are the most important basis for being selected for a job, being admitted to college or graduate school, or receiving a scholarship.

A combination of factors seem to affect a student's scholastic success. The most significant of these are intelligence and special abilities, motivation to succeed, and management of effective study methods. The latter two factors can be improved by efforts on the part of the student. The key to success is to identify your special abilities, interests, and potentials, and make the best use of them.

Careers in science, engineering, and technology require interest and ability in mathematics, science, and technical subjects. What school subjects do you like best? What are your strengths and weaknesses? What examples do you have as evidence of your abilities? Grades you have earned in past courses are good indicators; others are scores on achievement and aptitude tests. Your guidance counselor will interpret these scores for you. It is important to understand your special abilities and match them with potential career fields. Your career will be much more rewarding if it challenges you with work appropriate to your abilities and interests.

Your interests and your abilities go hand-in-hand when planning for potential careers. If you have a great deal of interest in an area but little natural ability, you will not be capable of performing the tasks competently. Likewise, if you have the ability to perform but little interest in an area, you are likely to be unhappy with that career. Natural ability plus an interest in a particular career will lead to more satisfaction with your work. Interest inventory tests have been designed to help you become aware of areas of interest. You may want to ask your guidance counselor to arrange for you to take one of these tests.

Many extremely bright students fail courses and many students with average intelligence excel. What accounts for this difference? Experts say it is partially the desire to learn the subject material and to achieve long-term goals. A strong desire and intention to learn results from interest in the subject material, the ability to comprehend the material, and a purpose for mastering the material. Motivation or a desire to succeed academically supplies the energy necessary to plan and practice effective study procedures. Motives are among the strongest influences on your behavior. They affect the amount of time and effort you are willing to exert in order to succeed. The most powerful motivations arise from your goals and aspirations. For example, if you really feel successful and happy when you have mastered complex mathematical equations, your career goal may be to become a mathematician. You will be motivated to study



Astronaut Jeffery A. Hoffman surveys the attachment of two snagging devices connected to the remote manipulator system (RMS) and effector of Discovery.

and learn basic mathematical principles. If your goal is acceptance at an Ivy League college and that depends upon earning straight As, you will dedicate yourself to efficient study patterns. If the praise of your parents and associates depends upon academic success and you want their praise, you will develop and follow effective study schedules. For these reasons, students with average intelligence and strong interests and goals usually will succeed in their studies. On the other hand, students gifted with intellectual abilities, but lacking interest and purpose for studying, may not be successful.

Goals and aspirations reflect how you picture yourself in terms of other people. They reflect your estimate of your chances of succeeding. Past successes and failures influence your goals and aspirations. Successful academic experiences increase confidence in your ability to succeed. They motivate you to continue the work necessary for repeated successes. Goal setting requires that you recognize your interests and abilities. Past experiences are good indicators of these interests and abilities. The most satisfied students seem to tie their aspirations closely to their levels of performance. They set flexible goals so that changes can be made. These changes may result from acquiring more information, more self-awareness, and more maturity. Flexible and attainable goals will prevent frustrations and disappointments.

If your goal is to become a scientist, engineer, or technician, you must have natural or acquired abilities, interests, and past successes in math, science, and technical subjects. Science and engineering careers require at least a bachelor's degree. This requires developing study patterns which will lead to success in college courses.

The following questions may help you clarify your goals and motives for pursuing a career in science, engineering, or technology. Spend some time thinking about these questions:

1. Do I really enjoy studying mathematics and science courses?
2. Do I have the interest and ability to succeed in these courses?
3. Why have I considered a career in science, engineering, or technology?
4. What special qualifications do I have for these kinds of jobs?
5. Do I really want to go to college?
6. Am I going because my friends are going?
7. Am I afraid I'll disappoint my parents if I don't attend college?
8. Can I handle the freedoms of college life — no curfews, managing my own expenses?
9. Am I responsible enough to complete assignments on time without the watchful eye of my parents or teachers?
10. Can I establish short-term educational goals for each semester or quarter?

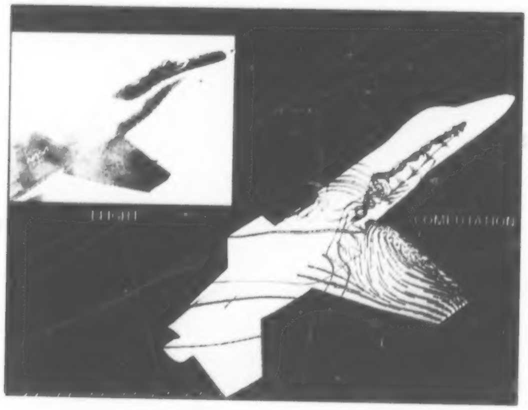
Efficient management of time and study procedures is also a significant factor in the formula for academic success. Efficiency implies maximum learning from the least time and effort expended. It requires organizing your time into effective study patterns that work for you. Planning a study schedule, and sticking to it, requires real effort. It means you must decide upon priorities.

A good rule of thumb is that, particularly for mathematics and technical courses, you should allow at least two hours for study for each hour spent in class.

As you develop a study schedule, you may find it necessary to give up or postpone activities that are fun, such as watching TV, going to the movies, talking on the phone, or just visiting with friends. Leisure time activities are important to all of us. However, they must be scheduled in relation to the study schedule. A sensible balance between leisure activities and study increases a student's chances of success. Your schedule for study should become a habit. Setting a time to study a certain subject increases the likelihood that you will retain the material and decreases the amount of time that you are likely to waste. Regularity seems to be the key as well as having one's priorities in order.

Developing effective and efficient study habits requires a knowledge of good study techniques and developing a study plan. Counselors, teachers, and a number of reference books can provide information on study skills. The following are some examples of techniques that should prove helpful.

NASA scientists "fly" computerized fighter in 3-D



(top left)

NASA researchers have "flown" a complete three-dimensional high-performance aircraft in a supercomputer for the first time.

The accuracy of solutions obtained from computational fluid dynamics is determined by comparing the solution with experimental data. For the F-18 aircraft, a large experimental database is gained from flight experiments conducted at NASA's Dryden Flight Research Facility; the leading edge extension is visualized by smoke released into the airstream. This is one indication that the computation can accurately resolve the features of the flow around the F-18 flying at high angle of attack.

The research is part of an effort to reduce wind tunnel testing of new aircraft designs. Supercomputer design has the potential to be less costly and gives data not available from wind tunnels, such as greater detail on flight conditions.

(top right)

Here, the computed surface pressure is represented using color contours. Blue represents regions of lower pressure, with pressure increasing through the green, yellow, and red regions. The regions are due to the leading edge of the wing and horizontal tail. The vortices provide additional lift to the aircraft flying at high angle of attack.

(bottom left)

The flow around an F-18 aircraft flying at a high angle of attack is computed here using computational fluid dynamics. The solution is analyzed using visualization techniques developed at NASA Ames Research Center. Flowfield features are highlighted using air particle traces. Traces show the flow patterns on the wings and nose and the burst of the vortices generated by the leading edge extensions. Also shown are relative size and strength of the vortices that develop on the forebody end.

(bottom right)

Scramjet engine exhaust is modeled in this supercomputer-generated image of an aerospace vehicle as part of the National Aero-Space Plane (NASP) Program. Red-to-pink indicates areas of highest air density, including the exhaust area (seen on the under surface at rear). Contour lines that ring the airplane indicate air density away from the surface at selected points.

Researchers at NASA's Langley Research Center are studying engine nozzle performance and exhaust effects on tail control surfaces. The image simulates wind tunnel test conditions at Mach 10 (approx. 6,500 mph).

Study Habits for the Student

The Physical Setting for Study

The physical setting for study affects concentration. Inability to concentrate is one of the major causes of inefficient use of study time. A good location makes it easy to start studying and helps concentration. Here are some points that may help:

1. Locate a good study desk or table located in an area away from distractions, such as other people talking, radio or TV, etc.
2. See that your study area is well lighted and wear glasses if you need them.
3. Study by yourself most of the time.
4. Keep study materials and books near at hand.
5. Make efficient use of study periods and free time during the day at school.

Planning Your Time for Study

Planning or budgeting your study time is very important. It is essential not to fall behind. Once you fall behind, it is very hard to catch up because there is always new work to be done. This is true of all subjects, but particularly so of mathematics, science, and foreign languages, where an understanding of the material already covered is usually essential to understanding the new material. Here are some points to remember in planning your study time:

1. Make and keep a study schedule.
2. Budget your study time.
3. Use odd moments for studying — take advantage of brief times during the day or enroute to school.

Better Listening and Note Taking

In school, as well as out of school, listening is very important. Good listening is an active process and requires concentration. Unlike reading, listening cannot be repeated (without potential embarrassment) if you miss the point the first time. The good listener is constantly thinking, evaluating, and drawing conclusions. In school, be alert to important ideas that are discussed in class. Your teachers and classmates will present material and explanations that you may not find in your textbooks. No one else can listen for you, and someone else's notes are not a good substitute for your own. Improving your listening habits and skills will improve all of your school work. Here are some aids that will help you to train yourself to listen better:

1. While listening, look for main ideas.
2. While listening, take notes (but don't try to take down everything).
3. Revise notes later to clear up points, and fix the material more firmly in your mind for future use.

Preview Reading Assignments

Previewing is important. It will save you time because it prepares you for better understanding and faster reading. It also will help you remember better. Here's how to preview:

1. Read over the title of the chapter. From the title try to get an idea of what the chapter will be about.
2. Look over the section headings.
3. Read the first and last paragraphs of the assignment.
4. Study the pictorial aids (illustrations, graphs, tables, etc.).
5. Take an inventory — ask yourself, "What do I know about the chapter?"

Reading the Assignment

Reading an assignment requires active thinking. What you derive from your reading depends largely on what you bring to it. Good reading requires interest, knowledge, and curiosity. For good reading:

1. Make up questions suggested by the main headings. Turn chapter headings and subheadings into questions.
2. Read to answer your questions. As you read, watch for the answers to the questions you have raised. It means reading all of the material required by your assignment, but you should be looking for your answers as you read.
3. Check your understanding by reciting the answers. After finding the answer to your question, repeat it to yourself. Stop reading at the end of each section, take time out, and repeat in your own words the answers to your question.
4. Reread when necessary to clarify any ideas of which you are unsure.

Note Taking

1. Jot down the *key words* and phrases in a preliminary outline. These notes are for your personal use and should be helpful to you. Notes will not supply all the information in detail, but they will give you a picture in outline form. When taking notes, keep these points in mind:
   a. Use your own words whenever possible.
   b. Confine your notes on a chapter to one side of a notebook sheet, if possible.
   c. Look over your notes a day or so after taking them. If they lack clarity and are cluttered or poorly organized, revise them.
2. Underline key words and phrases. *If you own the book*, you may prefer to underline key words and phrases in the book. However, do not underline a major fraction of the text.
3. Make diagrams to clarify ideas whenever this seems necessary or appears to be helpful.

Remembering

1. Find an interest in what you are studying.
2. Have a clear-cut grasp of the basic ideas. Clear understanding is necessary for good remembering.
3. Learn by wholes. Before you begin to study, know what the author's main theme is and how the main ideas are related. Then study the parts, the details which support the principal ideas.
4. Use more of your time in reciting than in rereading. Reciting helps you to remember better than rereading, because it forces you to think harder as you try to recall what you have learned.
5. Spot the key words and phrases. They will help you remember the ideas for which they stand.
6. Use as many of your senses in as many ways as possible. Try reading, reciting, writing out the answer, or sketching diagrams where appropriate.
7. Distribute your learning practice over several study periods. You will remember more from an assignment if you divide your learning of any subject over two or more separate periods of moderate length.
8. Learn for the future. If you memorize something only well enough to pass an examination, you will probably forget it quickly. If a fact or idea is worth learning at all, it is worth retaining. You should overlearn to compensate for the curve of forgetting.
9. Try to use what you learn. You tend to remember the things that you put to use. You might explain a lesson to someone, use a new idea during a discussion, try to relate new facts or concepts to ideas already studied in the same subject, in other subjects, in conversations, and in your own personal experience.
10. In most mathematics, science, and engineering courses, *problem-solving is essential to effective learning*. You should not only work all the assigned problems, but be sure you understand how you arrived at the answer(s).

Taking Examinations

Your best preparation for examinations is regular, day-by-day study. You should set some time aside for periodic review; at least one hour for each subject per week should consist of review. Here are some aids in preparing for examinations:

1. Plan a definite examination *study schedule* and stick to it.
2. Prepare and study a master outline of the subject. The master outline is a condensed version of all your notes on lectures, discussions, and readings.
3. Try to make up an exam for each course in which you expect to be tested. Then take it, check it. Be serious about it.
4. Get a good night's sleep before the examination.

Study Helps

Five Sources of Information

1. Use your own resources as much as possible:
   a. Get into the habit of relying on yourself. Do not lean on others any more than necessary. But, *know when and whom to ask for help.*
   b. Take an active interest in your studies.
   c. Use initiative when studying. Do some extra reading, whether or not it is assigned. Work some extra problems beyond those assigned. Be alert for current events that may have a bearing on what you are studying.
   d. Prepare carefully for class. Carry out the required assignments and master them. Do not let yourself fall behind.
   e. Participate actively in class. Enter into discussion. If there is something you do not understand, ask questions. Listen attentively and take notes during class.

2. Master your *textbook*. After yourself, your textbook is your most important study help. Get thoroughly acquainted with it.
3. Learn from *other students*. Listen actively to what your fellow students have to say during class discussions, recitations, question periods, and when they report on books read or projects undertaken. You may not agree with what they say, but this in itself contributes to learning.
   a. Join a dedicated study group.
4. Talk over with your teacher any questions you have concerning your work. When a question comes up about your work which you cannot answer, do not let the matter drop. Ask the question in class. If the answer given in class does not satisfy you, make an appointment with your teacher to discuss the matter further.
5. Browse in the library. This means reading here and there in books and magazines. You can browse for recreation or for study purposes. Browsing for information should be systematized and purposeful. You browse for information on a specific topic or to enlarge your background and knowledge of a particular subject. Some of the tools in the school library and in the public library that you should become familiar with are:
   a. Dewey Decimal System
   b. Card catalog/microfiche
   c. Dictionaries and glossaries
   d. Encyclopedia and its supplements
   e. Reader's Guide to Periodical Literature
   f. Library of Congress Classification System
   g. Indexes and abstracts

Read Faster

A problem that faces students in planning study time is the limited periods of time which can be set aside for that purpose. Reading faster (while keeping the level of comprehension high) can be a great asset.

To be an efficient reader, you must be a flexible reader. This means that you must realize that you cannot read everything at the same rate. You need to read technical books, or thought-provoking essays, more slowly than novels in order to think them through. Set your pace in accordance with the material to be covered. A more detailed discussion of improving your reading skills is given later.

If you plan to increase your speed, set reasonable goals. If you set too high a goal for yourself at first, you may soon become discouraged and give up altogether.

Spell Correctly

Misspelled words will result in lower grades. Your best friend is the dictionary; keep it handy when you write and if in doubt, look unfamiliar words up.

Build Vocabulary

Vocabulary building is necessary in all subject areas. The specialized vocabularies necessary to the understanding of science, social studies, math, foreign languages, and English are your responsibility. You can reserve a special place in your notebook for definitions that are necessary in each subject. Another approach is that of keeping vocabulary cards; put the word on one side and the definition on the other side of a small index card. You can use different colors for different subjects and keep the cards in a file box for handy reference and study.

Solve Mathematics and Science Problems Efficiently

Math, science, and engineering courses differ from many others in that the emphasis is on developing an ability to solve problems. Only if you can *apply* the knowledge gained in reading the textbook or listening to lectures, do you really understand the material. Therefore, practice in solving problems is extremely important — simply rereading the textbook is no substitute! Here are some pointers that may help you:

1. State the question in your own words; be sure you understand what is wanted.
2. Determine what process or formulas you need.
3. List the facts and figures required to answer the question.
4. Estimate your answer; make sure that its numerical value is at least reasonable based on your general knowledge of the subject or similar, previously worked examples.
5. Work out your answer in detail; compare it with your estimate. Be sure the units of the answer are correct or at least reasonable.

Skimming

You skim a page or paragraph by moving your eyes rapidly over the material in search of specific information. Headings, topic sentences, key words, and guide words can help you.

Improving Reading Rate and Comprehension

1. *Read regularly.* Practice is extremely important. Read as much as you can. Practice at least half an hour a day, more if possible.
2. *Begin with easy material.* At the outset, read material with a familiar vocabulary and ideas that can be grasped without effort. Get the feeling of moving along the lines of print quickly and comfortably while still making a conscious effort to increase your reading rate. Begin with fictionalized biography, science fiction, adventure stories, or other materials of interest to you.
3. *Work toward more difficult materials.* When you begin to see progress, step up to the next level of difficulty. Read news magazines and nonfiction on topics of current importance. Eventually, you will work to your rate on all types of reading. As soon as possible, turn your attention to your textbooks or other material directly applicable to your course work.
4. *Understand what you read.* Rate is determined primarily by the ability to comprehend. Read aggressively to answer questions. Before you start, turn the title into a question and keep asking, "What is the answer? What is the author saying?" Go in with a question; come out with an answer.
5. *Determine your purpose before you begin.* Decide why you are reading the particular selection and estimate its difficulty. Then set yourself to read at your most efficient rate in terms of these factors.
6. *Reduce vocalization in all silent reading.* Resolve to get the point by thinking the meaning, not by saying the words. Press to read faster than the top speed at which words can be pronounced.
7. *Read under progressive pressure.* During practice, read as rapidly as you can without jeopardizing comprehension. Read as if you were to take a quiz in 10 minutes and hadn't studied the lesson.
8. *Improve your vocabulary.* Strange words interfere with understanding. Since speed is a function of understanding, you will profit from a systematic attempt to increase your word knowledge. Keep a dictionary handy.
9. *Increase your store of knowledge.* Intelligent reading requires more than a mere knowledge of what the word means. The more you know about a subject, the better and faster you can read it.
10. *Don't make a fetish of speed.* Remember that speed without comprehension is counterproductive. Slow down as the occasion demands. Experts use many speeds, not just one.
11. *Be persistent.* There is no magic formula to show you how to double your rate overnight. Pressing to read faster and answer questions may be fatiguing at first. For a time, you may even seem more inefficient than before. But keep at it. Use any free time for additional practice. With a little persistence, more effective reading will become habitual.

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NASA Centers and Educational Programs

Introduction

A goal of NASA's Education Division is to maintain an adequate pool of scientists. engineers. and other professionals to meet national aerospace needs. Personnel from NASA Headquarters and the nine NASA field centers carry out this national education program covering the spectrum from elementary. middle. and high schools. to undergraduate. and graduate levels and post-graduate research programs. NASA's educational programs also recognize the importance of teachers and university faculty.

NASA offers educators a wide range of educational services including speakers. publications. audiovisual materials. software. advanced educational technology. curriculum assistance. electronic communications. in-school satellite programs. student programs. and training opportunities. Information about these programs follows.

Education Division NASA Headquarters

The Education Division is comprised of four branches: Elementary and Secondary. Higher Education. Technology and Evaluation. and Educational Publications. The Elementary and Secondary Branch conducts pre-college programs for teachers and students.

The Higher Education Branch administers undergraduate. graduate. doctoral. and post doctoral programs for university faculty and students. The Technology and Evaluation Branch develops and demonstrates the use of new teaching technologies. The Educational Publications Branch provides writing. editorial. illustration. design. layout. printing. and distribution services for NASA's educational materials.

Elementary and Secondary Programs

For information about the Elementary and Secondary Branch at NASA Headquarters. contact:

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Code FEE. NASA Headquarters
Washington. DC 20546-0001
(202) 358-1518

Each NASA field center has a Center Educational Programs Officer (CEPO). The CEPOs serve as the primary educational contacts for the elementary and secondary school communities in their geographic areas. The table on page 95 delineates the geographic regions.

Additionally. there are numerous Regional Teacher Resource Centers (RTRCs) located throughout the nation. You should contact the Center Educational Programs Officer for your state to determine the location of the nearest RTRC.

Summer High School Apprenticeship and Research Program (SHARP and SHARP Plus)

The Summer High School Apprenticeship and Research Programs are designed as research-based mentor programs. Both programs are established to increase the participation of African American. Hispanic. Alaska Native. Native American. and Pacific Islander students in mathematics. science. and engineering.

SHARP is operated at NASA field centers for selected students who reside within the commuting distance of the center. SHARP Plus is the residential counterpart on participating college and university campuses. The campuses are selected based on the retention and graduation of African American. Hispanic. and Native American students in engineering and science disciplines. For more information contact:

Mr. Ahmad Nurriddin, NASA Headquarters, Elementary and Secondary Branch, Code FEE, Washington, DC 20546-0001, (202) 358-1518.

Aerospace Education Services Program (AESP)

Aerospace Education Services Program specialists conduct workshops for teachers each summer at NASA field centers, elementary and secondary schools, and on college campuses. Workshops cover astronomy, aeronautics, life in space, principles of rocketry, Earth science, and remote sensing. A typical workshop includes how-to and hands-on activities to help teachers incorporate what they learn into classroom activities and programs to supplement existing curricula. Contact the Center Educational Programs Officer at the NASA field center that serves the school's geographic area, or contact:

Elementary and Secondary Branch
Code FEE, NASA Headquarters
Washington, DC 20546-0001
(202) 358-1518

Cooperative Education Program

A NASA-wide program, the Cooperative Education Program gives high school, college, and graduate students an opportunity to work at a field center while completing their education. Each field center negotiates its own cooperative agreements with schools in its geographic area. Contact the center Personnel Officer at the NASA field center that serves the school's geographic area, or contact:

NASA Headquarters
Attn: Catherine Zegowitz
Mail Code FPH
Washington, DC 20546-0001
(202) 358-1570

Higher Education Programs

For more information about the Higher Education Branch at NASA Headquarters, contact:

Ms. Elaine Schwartz, Chief
Higher Education Branch
Code FEH, NASA Headquarters
Washington, DC 20546-0001
(202) 358-1531

Each NASA field center employs a University Affairs Office (UAO). In addition to conducting a variety of programs for university students and faculty, the UAO serves as a focal point for information to the university community about research, grant, and fellowship opportunities, and other university-related activity at the center.

Graduate Student Researchers Program

This program awards fellowships to graduate students whose research interests are compatible with NASA programs. Approximately 150 new awardees are selected each year based on a competitive evaluation of academic qualifications, the proposed research or plan of study, and where appropriate, the planned utilization of NASA research facilities. For further information, please contact:

Higher Education Branch
Education Division
Mail Code FEH, NASA Headquarters
Washington, DC 20546-0001
(202) 358-1531

NASA Space Grant and Fellowship Program

In 1987 Congress passed legislation creating the National Space Grant College and Fellowship Program, which represents a bold, sweeping commitment to maintaining this nation's preeminence in aeronautics and space science and technology. NASA, given responsibility for designing and managing the Space Grant program, developed the following objectives:

- to establish a national network of universities with interests and capabilities in aeronautics, space, and related fields;
- to encourage cooperative programs among universities, aerospace industry, and federal, state, and local governments;
- to encourage interdisciplinary training, research, and public service programs related to aerospace;
- to recruit and train professionals, especially women, underrepresented minorities, and persons with disabilities, for careers in aeronautics and space-related science and engineering; and,
- to develop a strong science, mathematics, and technology education base from elementary through university levels.

Under the Space Grant program a national network of public and private colleges and universities with varying degrees of aeronautics and space-related resources and capabilities are joined by space-related industry, state and local governments, and nonprofit organizations. Space Grant consortia have been established in every state, the District of Columbia and Puerto Rico. Each consortium receives NASA funds to be used in implementing a balanced program of research, education, and public service.

More information and a list of Space Grant Programs Directors may be obtained by writing to:
National Space Grant College and
Fellowship Program
Higher Education Branch
Mail Code FEH
NASA Headquarters
Washington, DC 20546-0001

Education Technology Programs

Spacelink— Spacelink is an information access system that allows individuals to log on and receive news about current NASA programs and activities and other space-related activities and information, including historical and astronaut data, lesson plans and classroom activities, and even entire publications. Although primarily intended as a resource for teachers, anyone with a personal computer and modem can access the network.

Spacelink Direct Dial via Modem:
(205) 895-0028
Data word format: 8 data bits, no parity, and 1 stop bit

Internet Address:
spacelink.msfc.nasa.gov

Spacelink Administrator
Marshall Space Flight Center
Mail Code CA-21
Huntsville, AL 35812
(205) 544- 6527

Satellite Videoconference

During the school year, a series of educational programs is delivered by satellite to teachers across the country. The content of each videoconference varies, but all cover aeronautics or space science topics of interest to the educational community. The broadcasts are interactive; a number is flashed across the bottom of the screen, and viewers can call collect to ask questions or take part in a discussion. For further information contact:

Dr. Malcom Phelps
Technology and Evaluation Branch
Education Division
Code FET, NASA Headquarters
Washington, DC 20546-0001
(202) 358-1540

Videoconference Coordinator
NASA Aerospace Education Services Program
Oklahoma State University
300 N. Cordell
Stillwater, OK 74078
(405) 744-7015

Teacher Resource Center Network— to make information available to the educational community, the Education Division has created the NASA Teacher Resource Centers (TRCs) which contain a wealth of information for educators: publications, reference books, slides, audio cassettes, videocassettes, tele-lecture programs, computer programs, lesson plans and activities, and lists of publications available from government and nongovernment sources.

Because each NASA field center has its own areas of expertise, no two TRCs are exactly alike. Phone calls are welcome if you are unable to visit the TRC that serves your geographic area. See page 95 for geographic regions.

Central Operation of Resources for Educators (CORE)

CORE is a centralized mail-order audiovisual library for educators; no printed materials are available. Submit a written request on your school letterhead for a catalogue and order forms. Orders are processed for a small fee that includes the cost of the media.

NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074
Phone: (216) 774-1051 Ext. 293 or 294

NASA Educational Offices Higher Education Programs

If you are attending a college or university, you may contact the following offices for information about programs and opportunities (e.g., Graduate Students Researchers Program) for which you may be eligible.

University Affairs Officer
Code 241-3
Ames Research Center
Moffett Field, CA 94035
Telephone: (415) 604-5802

University Affairs Officer
Mail Stop 600
Goddard Space Flight Center
Greenbelt, MD 20771
Telephone: (301) 286-9690

Education Director
Mail Code 180-900
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109-8099
Telephone: (818) 354-8251

University Affairs Officer
Mail Stop AHU
Johnson Space Center
Houston, TX 77058
Telephone: (713) 483-4724

University Affairs Officer
Mail Code HM-CIU
Kennedy Space Center
Kennedy Space Center, FL 32899
Telephone: (407) 857-2512

University Affairs Officer
Mail Stop 105-A
Langley Research Center
Hampton, VA 23681-0001
Telephone: (804) 864-4000

University Affairs Officer
Mail Stop 3-7
Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135
Telephone: (215) 433-2956

University Affairs Officer
Mail Stop DX01
Marshall Space Flight Center
Marshall Space Flight Ctr., AL 35812
Telephone: (205) 544-0997

University Affairs Officer
Science and Technology Branch
Mail Code HA10
Stennis Space Center
Stennis Space Center, MS 39529
Telephone: (601) 688-3880

NASA Educational Offices Elementary and Secondary Programs

If you are an elementary, junior high, or high school level student or you are in the twelfth grade or less, you may contact the following offices for information about programs and opportunities (e.g., Summer High School Apprenticeship Research Program) for which you may be eligible.

If you live in:

Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming

Chief, Educational Programs Branch
Mail Stop T025
NASA Ames Research Center
Moffett Field, CA 94035
(415) 604-5543

Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont

Chief, Educational Programs
Mail Code 130
NASA Goddard Space Flight Center
Greenbelt, MD 20771
(301) 286-7207

Colorado, Kansas, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas

Educational Programs Officer
Mail Code AP-4
NASA Johnson Space Center
Houston, TX 77058
(713) 483-1257

Florida, Georgia, Puerto Rico, Virgin Islands

Chief, Education and Awareness Branch
Mail Code PA-EAB
NASA Kennedy Space Center
Kennedy Space Center, FL 32899
(407) 867-4444

Kentucky, North Carolina, South Carolina, Virginia, West Virginia

Educational Office
Mail Stop 400
NASA Langley Research Center
Hampton, VA 23681-0001
(804) 664-3312

Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin

Chief, Office of Educational Programs
Mail Stop 7-4

NASA Lewis Research Center
21000 Brookpark Road
Cleveland, OH 44135
(216) 433-5583

Alabama, Arkansas, Iowa, Louisiana, Missouri, Tennessee

Chief, Education Branch
Mail Code CA-21
NASA Marshall Space Flight Center
Marshall Space Flight Center, AL 35812
(205) 544-0213

Mississippi

Educational Programs Office
Mail Stop HA00
NASA John C. Stennis Space Center
Stennis Space Center, MS 39529
(601) 688-1107

For NASA education and training programs at Historically Black Colleges and Universities, Hispanic Serving Institutions and Tribal College
Contact: Division Manager
Minority University Education and Research Division
Code EU
Washington, DC 20546-0001
(202) 358-0970

Additional education programs are offered at the Jet Propulsion Laboratory. For information contact: Education Director
Mail Code 180-205
Jet Propulsion Laboratory
4800 Oak Grove Drive
Pasadena, CA 91109-8099
Telephone: (818) 354-8592

U.S. Department of Energy Laboratory and Facility-Based Science Education Programs

The U.S. Department of Energy's scientific research laboratories and facilities are available as resources for teachers and students. For more information on programs available in your area, please contact the facility nearest you.

Department of Energy
Office of University and Science
Education Programs
ER-80
1000 Independence Ave. SW
Washington, DC 20585

Ames National Laboratory
Ames Laboratory Education Program
Iowa State University
108 Office, Laboratory Bldg.
N-156 Quadrangle
Ames, Iowa 50011

Argonne National Laboratory
Director of Educational Programs
ANL
9700 South Cass Ave., Bldg. 223
Argonne, Illinois 60439

Associated Western Universities
AWU
4190 S. Highland Drive
Suite 211
Salt Lake City, Utah 84124

Bates Linear Accelerator Center
BATES/MIT
P.O. Box 846
Middleton, Massachusetts 01949

Bonneville Power Administration
BPA
P.O. Box 3621 SPB
Portland, Oregon 97208-3621

Brookhaven National Laboratory
Head, Office of Educational
Programs
BNL
30 Bell Avenue, Bldg. 490
Upton, New York 11973

Continuous Electron Beam Accelerator Facility
Education Project Manager
CEBAF
12000 Jefferson Avenue
Newport News, Virginia 23606

EG&G Mound-Applied Technologies
Precollege Program Committee
EG&G Mound-Applied Technologies
P.O. Box 3000
Miamisburg, Ohio 45343

Fermi National Accelerator Laboratory
Manager, Education Office
P.O. Box 500
Batavia, Illinois 60510

Fernald Environmental Management Project
Environmental Technology,
Education, and Community Outreach
Programs
P.O. Box 398704
Cincinnati, Ohio 45239-8704

Idaho National Engineering Laboratory
Director of External Affairs
INEL
P.O. Box 1625, MS 1131
Idaho Falls, Idaho 83415-3500

Inhalation Toxicology Research Institute
ITRI
P.O. Box 5890
Albuquerque, New Mexico 87185

Kansas Field Office (Allied-KC)
Allied Signal Aerospace Company
P.O. Box 419159
2000 East 95th Street
Kansas City, Missouri 64141-6159

Lawrence Berkeley Laboratory
Director, Center for Science &
Engineering Education
LBL
University of California
Bldg 938C
One Cyclotron Road
Berkeley, California 94720

Lawrence Livermore National Laboratory
Manager of Human Resources
Planning Development
LLNL
P.O. Box 808
Livermore, California 94550

Los Alamos National Laboratory
Office of University Relations
LNL
P.O. Box 1663-P278
Los Alamos, New Mexico 87545

Morgantown Energy Technology Center
Deputy Associate Director
METC
P.O. Box 880
Morgantown, West Virginia
26507-0880

National Renewable Energy Laboratory
NREL
1617 Cole Boulevard Bldg. 17
Golden, Colorado 0401-3933

Naval Petroleum Reserves in California (NPR)
P.O. Box 11
28590 Highway 119
Tupman, California 93276

Nevada Test Site (NVO)
Office of External Affairs
NTS
P.O. Box 98518
Las Vegas, Nevada 89193-8518

Northwest College and University Association of Science
NORCUS
100 Sprout Road
Richland, Washington 99352-1643

Oak Ridge Institute for Science and Education
Chairman, Science/Engineering Education Division
ORISE
P.O. Box 117
Oak Ridge, Tennessee 37831-0117

Oak Ridge National Laboratory
Director, Science Educational Programs
ORNL
105 Mitchell Rd.
MS-6496
Oak Ridge, Tennessee 37831-6496

Pacific Northwest Laboratory
Manager, Pre-University Education
PNL
P.O. Box 999, MS-KI-66
Richland, Washington 99352

Pinellas Plant
P.O. Box 2908
Largo, Florida 34649

Pittsburgh Energy Technology Center
Associate Director for Research & Development
PETC
P.O. Box 10940
Pittsburgh, Pennsylvania 15236

Princeton Plasma Physics Laboratory
Education Programs Office
PPPL
P.O. Box 451-Route 1
Princeton, New Jersey 08543

Raytheon Services Nevada
222 S. Rainbow Blvd., Suite 213
Las Vegas, Nevada 89128

Rocky Flats Plant
P.O. Box 464
Golden, Colorado 80402-0464

Sandia National Laboratories (SNL), Albuquerque
Educational Programs
SNL-A
ORG. 9000-B
P.O. Box 5800
Albuquerque, New Mexico 87185

Sandia National Laboratories (SNL), Livermore
Education Project Leader
SNL-L P.O. Box 969
Livermore, California 94551-0969

Savannah River Ecology Laboratory
SREL
Drawer E
Aiken, South Carolina 29802

Savannah River Technology Center (SRTC)
Educational Programs
Westinghouse Savannah River Company
P.O. Box 616, Bldg. 773-42A
Aiken, South Carolina 29808

Stanford Linear Accelerator Center
Education Office
SLAC
P.O. Box 4349, Bin-81
Stanford, California 94309

Strategic Petroleum Reserve (SPR)
900 Commerce Road East
New Orleans, Louisiana 70123

Superconducting Super Collider
Manager of Education Programs
SSC
2550 Beckleymeade Avenue
MS-2071, Bldg. 4
Dallas, Texas 75237

Western Area Power Administration
WAPA
P.O. Box 3402
Golden, Colorado 80401-3402

Westinghouse Hanford Company (WHC)
P.O. Box 1970
Richland, Washington 99352

The National Technical Association

The National Technical Association (NTA), founded in 1926, is an organization of scientists, engineers, architects, and technicians, including both professionals and students. Its goals include developing and integrating the technical input of underrepresented minorities into the total scientific process and furthering an awareness of their technical contributions to the world's societies. NTA's activities include improving technical interchange among minorities, providing career opportunity information to minorities, and motivating and assisting minority youth toward pursuing technical careers.

NTA, headquartered in Washington, DC, has numerous professional chapters throughout the US (listed below) as well as student chapters, mostly associated with major colleges and universities. It holds an annual national conference, other events such as Student Technical Symposia, and publishes a quarterly journal. For further information about NTA and its chapters, contact:

National Technical Association
Attn: Executive Director
P.O. Box 7045
Washington, DC 20032-7045
Tel. (202) 829-6100
Fax: (703) 684-3952

*National Technical Association Professional Chapters by Region**

Region 1

Delaware Valley Chapter
Philadelphia, PA

Pittsburgh Chapter
Pittsburgh, PA

King of Prussia Chapter
Valley Forge, PA

Buffalo Chapter
East Amherst, NY

New York Chapter
Brooklyn, NY

Region 2

Baltimore Chapter
Baltimore, MD

Washington Chapter
Washington, DC

Hampton Roads Chapter
Hampton, VA

Petersburg Chapter
Petersburg, VA

Richmond Chapter
Richmond, VA

Research Triangle Chapter
Greensboro, NC

Region 3

Augusta Chapter
Augusta, GA

Huntsville Chapter
Huntsville, AL

South Florida Chapter
Miami, FL

Space Coast Chapter
Titusville, FL

Jackson Chapter
Jackson, MS

Region 4

Indianapolis Chapter
Indianapolis, IN

Detroit Chapter
Highland Park, MI

Akron Chapter
Akron, OH

Cincinnati Chapter
Cincinnati, OH

Cleveland Chapter
Cleveland, Ohio

Columbus Chapter
Columbus, OH

Dayton Chapter
Huber Heights, OH

Region 5

St. Paul Chapter
St. Paul, MN

Region 6

Chicago Chapter
Chicago, IL

Research Corridor Chapter
Woodbridge, IL

Region 7

Dallas-Fort Worth Chapter
Garland, TX

Houston Chapter
Houston, TX

Metro Area New Orleans Chapter
New Orleans, LA

Region 9

Greater Pomona Valley
Diamond Bar, CA

San Francisco Bay Chapter
San Francisco, CA

Region 10

Connecticut Chapter
North Haven, CT

Virgin Islands Chapter
St. Thomas, USVI

**Regions are defined by the first digit of postal zip code (except Region 10=Zip code 0xxxx).*

Department of Energy

National Science Teachers Association

National Aeronautics and
Space Administration

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